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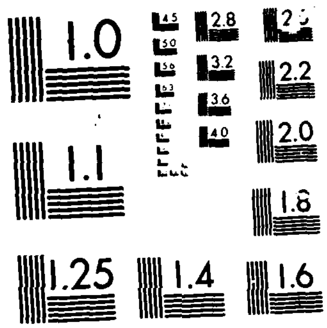

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US Army Corps of Engineers
Construction Engineering Research Laboratory

USA-CERL

TECHNICAL REPORT N-86/04
February 1986
Design and Operational Techniques for Air Pollution Control

Air Pollution Aspects of Modular Heat-Recovery Incinerators

by
Martin J. Savoie
Gary W. Schanche
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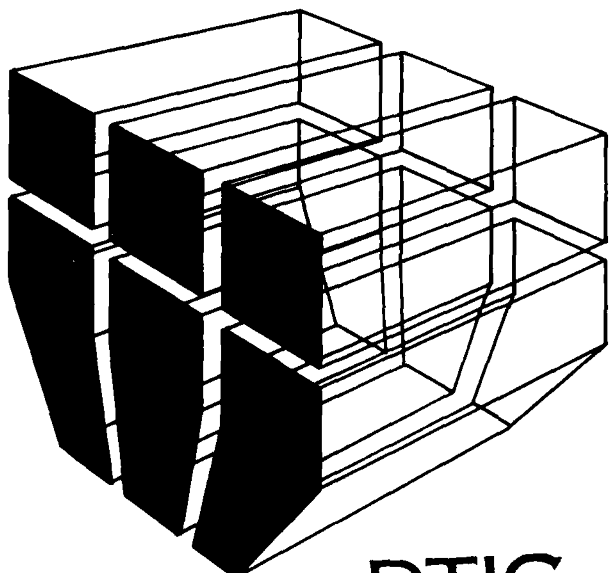

This report provides technical information on modular solid waste heat-recovery incinerators (HRIs), air pollution regulations that apply to HRIs, air pollutant emissions from currently marketed HRIs, and air pollution control techniques for HRIs. The information will be useful to Army installations, Major Commands, and Corps of Engineers Districts that must plan and design HRI facilities.

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FOREWORD

This investigation was conducted for the Office of the Assistant Chief of Engineers (OACE). The work was done by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL) under Project 4A162720A896, "Environmental Quality Technology"; Technical Area B, "Environmental Design and Construction"; Work Unit 042, "Design and Operational Techniques for Air Pollution Control." The OACE Technical Monitor was H. Musselman, DAEN-ZCF-U.

Dr. Ravinder Jain is Chief of the USA-CERL-EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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CONTENTS

FIGURES

TABLES

TABLES (Cont'd)

AIR POLLUTION ASPECTS OF MODULAR HEAT-RECOVERY INCINERATORS

1 INTRODUCTION

Background

Heat-recovery incinerators (HRIs) are very viable alternatives to sanitary landfills for disposal of solid waste from all types of Army installations. They may be of particular value to Army installations whose sanitary landfills are nearing their filled capacities. The addition of an HRI facility would extend the life of the existing landfill by as much as 30 times. It would also offer the benefit of producing usable steam while reducing the volume of refuse to be disposed. While the HRI facility does not have the same energy conversion efficiency as a boiler designed for steam production, it can return about 50 percent of the heat content of the refuse that it burns to useful steam. Non-Department of Defense HRI facilities that use HRIs of less than 50 tons/day have had reasonable success. The Army currently has five HRIs either in operation or under construction, with 12 more planned. Depending on facility size, HRI construction costs will range from $2 million to $7 million (FY83 dollars) apiece. In each of the five constructed HRIs, there have been significant air pollutant emissions problems. These problems have greatly delayed Army acceptance of the HRI facilities and could result in much greater costs.

Many of these air-pollution-related problems could have been avoided in the project planning phase if enough planning information had been available. Unfortunately, very little information is available on the air pollutant emissions characteristics of various types of HRI units. Information on applicable air pollution control technologies and HRI operating characteristics is also scarce. In addition, air pollutant emissions regulations vary greatly among states. Therefore, with an investment of $70 million (FY83 dollars) at stake, the Army requires guidance on the air pollution problems associated with HRIs.

Purpose

The purpose of this report is to provide technical information on modular solid waste incineration, applicable air pollution regulations, expected emissions, and applicable air pollution control technologies to installations, Major Commands, and Corps of Engineers Districts involved in planning or designing HRI facilities.

Approach

A four-phased research approach was used in this project. First, available modular HRI technologies were reviewed. The review was limited to modular units because custom field-erected HRI units are not cost-competitive in the facility size range of interest to the Army (20 to 75 tons/day* capacity). Second, Federal and State air quality

*Metric conversion factors are provided on p 57.

regulations governing HRIs were reviewed. Third, a survey of air pollutant emissions from modular HRI units currently in the marketplace was conducted. Finally, applicable air pollution control techniques for HRIs were reviewed.

Mode of Technology Transfer

It is recommended that the data in this report be incorporated into an Engineer Technical Letter on planning and designing HRIs; the information may impact on guidance contained in Technical Manual (TM) 5-815-1, *Air Pollution Control Systems for Boilers and Incinerators* (Department of the Army, 15 November 1980).

2 MODULAR INCINERATION

"Modular incinerator" is a popular expression used to describe packaged or factory pre-built incinerators. Major incinerator components, such as the primary and secondary combustion chambers, charging hopper, ash-handling system, heat-recovery boiler, and air pollution control equipment, are fabricated at the factory. These units can range in size from 1 to 150 tons per day (TPD). Sizes typically range from 10 to 50 TPD. The 50-TPD unit is quite popular because it is the cutoff size for the U.S. Environmental Protection Agency (USEPA) New Source Performance Standard for Incinerators. Units sized at 50 TPD or less are not regulated by this standard. Modular incinerators are available that burn Incinerator Institute of America (IIA) waste Type 0 through Type 6 with or without heat recovery. Modular incinerators are commonly installed in combinations of two or more units of the same size. This provides for better "turndown" ratios and consistent operating practices and reduces inventory parts requirements. Modular design also provides for easy expansion to accommodate growing waste reduction needs.

Two types of incinerators are available: starved air and excess air. Starved-air units are divided into a primary and a secondary combustion chamber and are usually batch-fed. Figures 1 through 4 are schematics of a typical starved-air modular incinerator. In the primary chamber, waste is burned at conditions less than the stoichiometric air requirements, which is the amount of air needed for complete combustion of the waste. The temperature in the primary chamber is maintained at about 1200°F. This produces a highly combustible gas that is then burned in the secondary chamber, with excess air, at about 1800°F. An auxiliary burner in the secondary combustion chamber maintains these high temperatures for complete combustion. In most starved-air units, the secondary combustion temperatures are self-sustaining and the auxiliary burner operates intermittently.

Excess-air units also consist of a primary and a secondary chamber. These units differ from starved-air units in that they introduce excess air into both combustion chambers. Since more air is supplied to the primary chamber, there is more turbulence in the primary chamber. This provides for better combustion of the waste, but also suspends more flyash particles in the gas stream. The primary combustion chambers in excess-air units tend to be larger than starved-air units in order to reduce the high gas velocities caused by the addition of excess air. Most excess-air units are designed with some type of moving bed or grate in the primary chamber. Figures 5 through 8 are schematics of typical excess-air modular incinerators. Mixing the waste in the primary chamber increases burnout of the waste and decreases retention time in the incinerator. Mixing also suspends particulates that may be carried out in the flue gas. Bed types include reciprocating grates, traveling grates, augered bed, basket grate, and rotary kiln. Applications of the rotary kiln have also been extended to starved-air incineration. The secondary chamber of excess air units also uses auxiliary burners to maintain combustion temperatures at 1600 to 1800°F.

Heat recovery from modular incinerators is obtained by passing the hot flue gas through a heat exchanger. The heat exchanger is usually a fire-tube or a water-tube boiler. Heat exchangers are available as packaged or modular units also. Figure 9 is a schematic of a typical starved-air modular HRI with a fire-tube boiler. Boilers are available that supply heat in the form of hot water, low-pressure steam, and high-pressure steam.

The popularity of incineration as a solid waste disposal technique declined greatly in the early 1970s with the advent of the Clean Air Act. Incinerators before the Clean Air Act were largely excess-air units without air pollution control. These incinerators produced large amounts of particulates, much of which were allowed to exit via the stack into the surrounding atmosphere. Modern incinerators, both excess-air and starved-air, use controlled air and high temperature afterburner techniques that have improved combustion and reduced the amount of particulate emissions. Because of the polluting nature of its predecessors, the modern modular incinerator's evolution has been watched closely by environmental regulatory agencies. Although the USEPA does not closely regulate small modular incinerators, most states have developed stringent regulations for incinerators.

A step-by-step procedure for evaluating the feasibility of a heat-recovery incinerator at any Army installation within the Continental United States, called Heat Recovery Incinerator Feasibility (HRIFEAS), has been developed. It is accessible through the Environmental Technical Information System (ETIS).[1] The procedure looks at an installation's solid waste production, desired HRI facility operating schedule, and steam demand requirements. The system then sizes the facility and provides information on capital cost and O&M costs. It will also identify the amount of fuel saved by burning refuse, the amount of auxiliary fuel consumed, and the amount of ash produced. Finally, HRIFEAS will run a preliminary Energy Conservation Investment Program (ECIP) calculation and determine if the proposed HRI facility will qualify under ECIP criteria. For more information about HRIFEAS, contact USA-CERL.

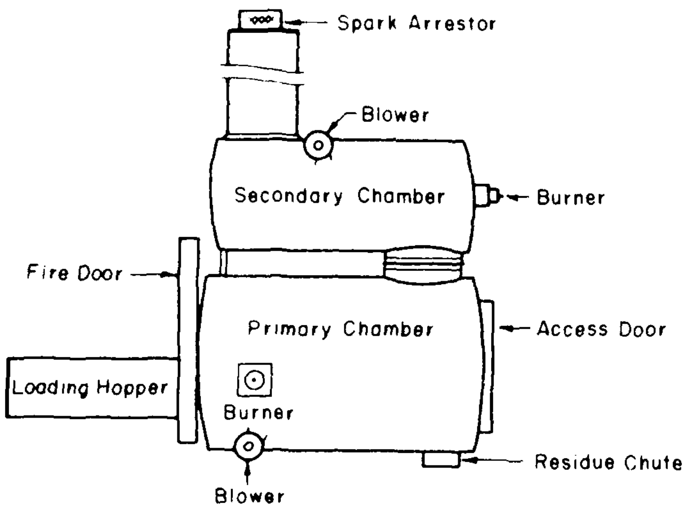

Figure 1. Starved-air incinerator--configuration of two horizontal cylindrical chambers with one above the other. Manufactured by Environmental Control Products, Comtro, Morse Boulger, Econo-ther, Kelley, Consumat, and Smokatrol. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

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[1] Webster, R. D., et al., *Modification and Extension of the Environmental Technical Information System for the Air Force*, Technical Report N-81/ADA079441 (USA-CERL, 1979).

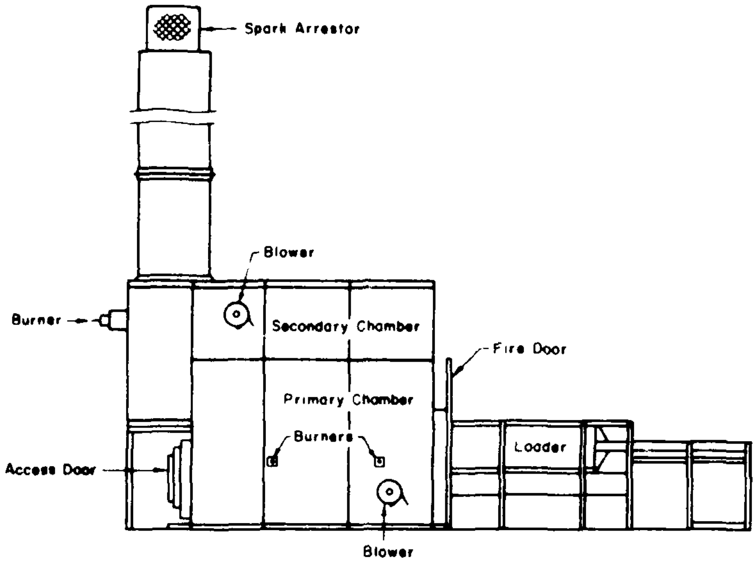

Figure 2. **Starved-air incinerator—configuration of two horizontal rectangular chambers with one above the other.** Manufactured by Washburn and Granger, Basic, and Simonds. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

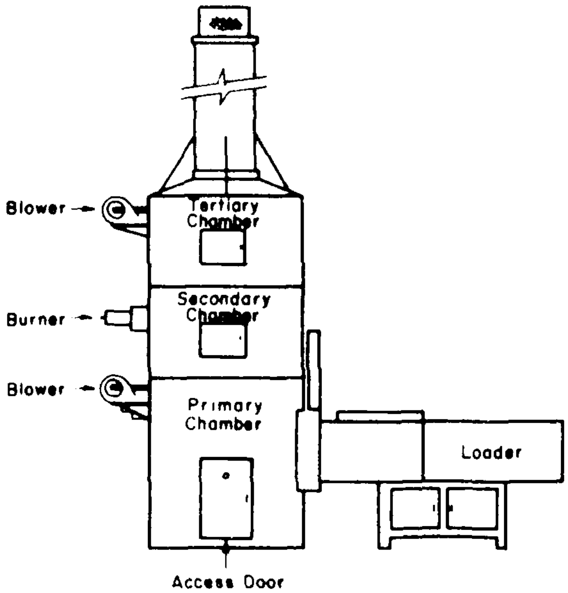

Figure 3. **Starved-air incinerator—configuration of Burnzol's two vertical cylindrical chambers with one above the other.** (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

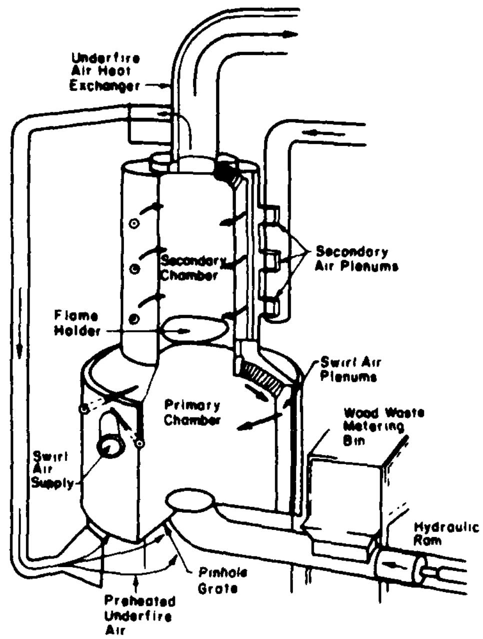

Figure 4. Starved-air incinerator—configuration of Lamb-Cargate's two vertical cylindrical chambers with one above the other. (From A. E. Martin, ed., *Small* Scale Resource Recovery Systems [Noyes Data Corporation, 1982].)

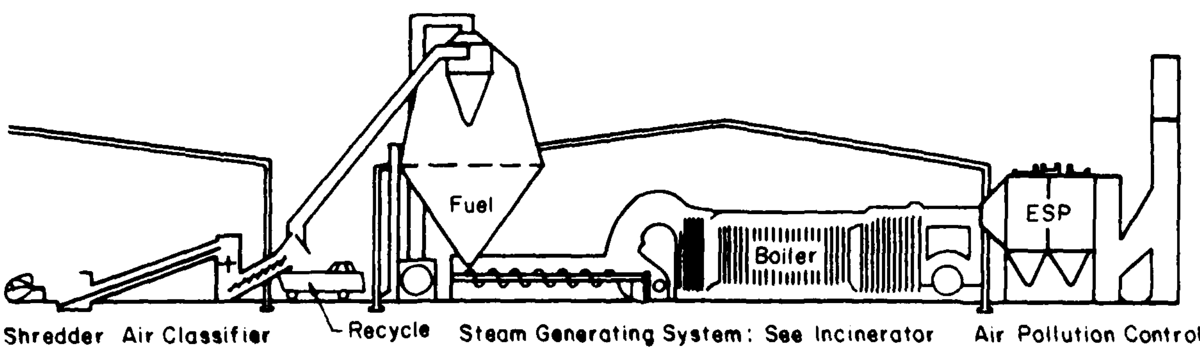

Figure 5. Augered-bed excess-air incinerator configuration with auger in the primary chamber. Manufactured by Scientific Energy Engineering. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

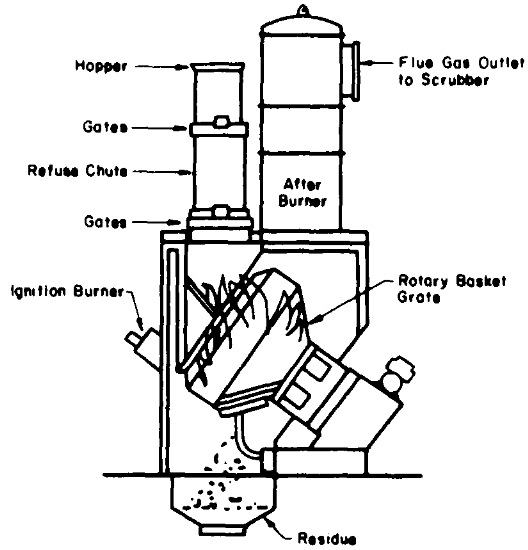

Figure 6. Rotary-basket-grate excess-air incinerator configuration with rotary grate in the primary chamber. Manufactured by Giery. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

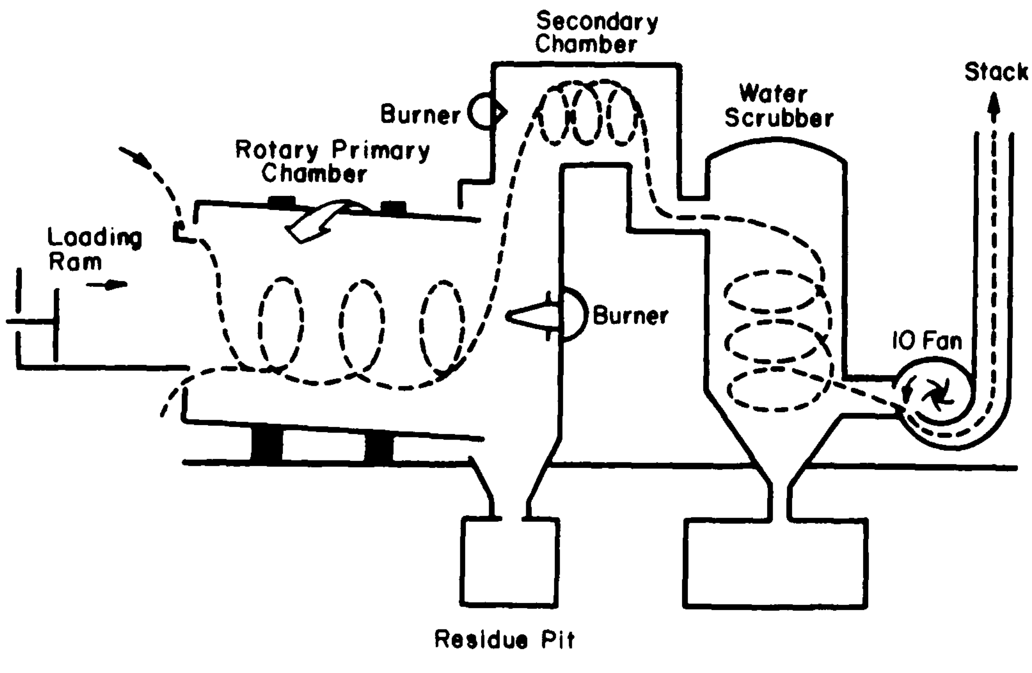

Figure 7. Rotary-chamber excess-air incinerator configuration with a rotary primary chamber. Manufactured by C. E. Bartlett. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

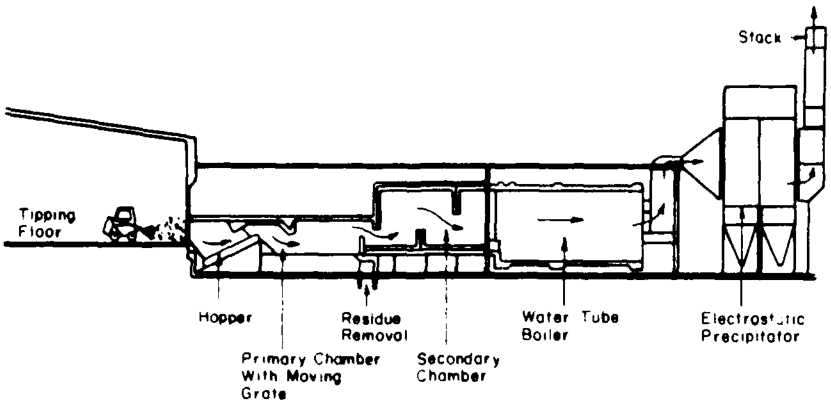

Figure 8. Moving-grate excess-air incinerator configuration with two horizontal rectangular chambers aligned one after the other, with heat recovery. Manufactured by Clear Air. (From A. E. Martin, ed., *Small Scale Resource Recovery Systems* [Noyes Data Corporation, 1982].)

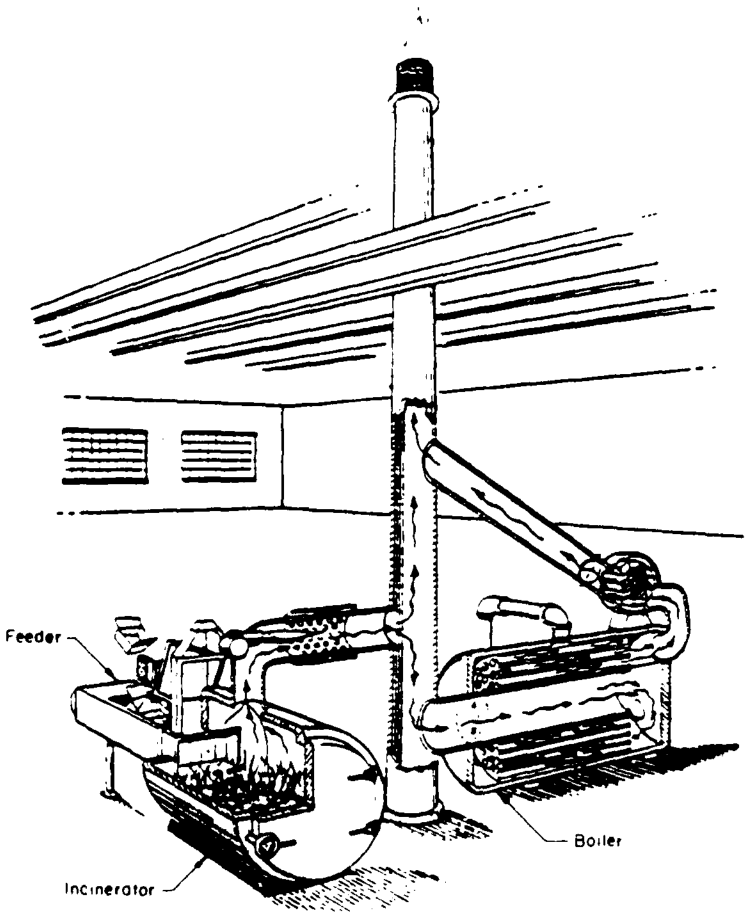

Figure 9. Starved-air incinerator with heat recovery. (From *Source Category Survey: Industrial Incinerators*, EPA-450/3-80-013 [USEPA, Emission Standards and Engineering Division, 1980].)

3 AIR POLLUTION REGULATIONS

The Clean Air Act (as amended) contains many elements to regulate emissions. The two major elements for regulating emissions are the Non-Attainment program and the Prevention of Significant Deterioration (PSD) program. These programs are designed to bring areas of noncompliance with the National Ambient Air Quality Standards (NAAQS) into compliance and to protect areas that meet or exceed these standards. Two special standards also apply to incinerators: the New Source Performance Standards (NSPS) and the National Emission Standards for Hazardous Air Pollutants (NESHAPS). Each state must adopt these Federal regulations into its own program for monitoring air quality, the State Implementation Program (SIP), or develop more stringent regulations of its own. The goal of the SIP is to achieve and maintain PSD air quality levels. Many states have developed their own regulations for both attainment and nonattainment areas. In most cases this has resulted in state emission standards for specific sources of air pollution, such as incinerators. The predominant SIP emission standards for incinerators limit particulates and visible emissions. Most states also have qualitative fugitive dust and odor regulations for incinerator facilities.

The primary regulatory agency for modular incinerator air pollution control is normally the state EPA. All states require incinerator sources to file some form of permit to construct and operate the facility. Generally, the permit process consists of two parts: the construction permit and the operation permit. The construction permit application contains the facility design data and estimates of potential air pollutant emissions. Appendix A gives an example of a permit application. Since an HRI is a boiler (indirect heat exchanger) and an incinerator, the permit application must contain information on both. Following is a partial list of information that may be required on an incinerator's permit application.

1. Facility design information, including installation date, type of incinerator and heat exchanger, blueprints, rated capacity, use (space heat, power, process heat), operating schedule, and cost

2. Fuel characteristics for both primary and secondary fuels, including ash, sulfur, and BTU content

3. IIA waste category, along with the percentage of materials, including plastic, rubber, and incombustibles

4. Amount of fuel used, storage, source, and supplier

5. Ash disposal and dust control

6. Process conditions, including primary and secondary chamber combustion temperatures and percent excess air

7. Combustion air type (forced, induced, or natural draft), and location of underfire, overfire, and secondary chamber air ports

8. The number, size, and airflow through combustion air ports

9. Flue gas stack diameter, height, and construction materials

10. The number of stack sampling ports and stack height above adjacent structures

11. Auxiliary equipment such as dampers, and primary and secondary chamber burners

12. Prior stack test data and estimates of all potential air pollutants

13. Location and type of stack gas monitoring equipment

14. Pollution control equipment design parameters, including efficiency, gas flow, and energy requirements

15. Manufacturers' guarantees and specifications on indirect heat exchanger, incinerator, and pollution control equipment.

Operating permits are issued after successful completion of a test run at the facility. A successful test run is often determined by a stack test for particulates. Some states accept prior emissions data from identical units operating at similar conditions instead of requiring individual sources to perform emission testing. Exemption from the stack test is usually approved on a case-by-case basis. Incinerators with new designs or those which lack emissions data will require a complete stack test to determine compliance with particulate and visible emission regulations.

For specific information on new source permits and regulations, installations should contact the appropriate regulatory authority. Appendix B lists the regulatory agencies to contact for permit information for states with DA incinerators programmed or currently in operation.

Particulate Emission Regulations

Federal Regulations

The USEPA method for determining particulate emissions is contained in the *Code of Federal Regulations* (CFR) Title 40, Chapter 1, Appendix A, "Method 5 - Determination of Particulate Emissions From Stationary Sources." Particulate matter measurements from incinerators are usually obtained by USEPA Reference Method 5 sampling procedures or an equivalent method. Other equivalent methods used include American Society for Testing Materials (ASTM) D 3685-78 and American Society of Mechanical Engineers (ASME) Power Test Codes PTC-27 sampling procedures. Most states have adopted the USEPA method, which is the recognized standard sampling procedure.

The Federal regulation limiting particulate emissions from incinerators is contained in Title 40, Part 60, Subpart E, "Standards of Performance for Incinerators." This regulation limits incinerator particulate emissions to 0.08 grains (gr) per dry standard cubic foot (gr/dcsf) corrected to 12 percent carbon dioxide. Incinerators affected by this regulation are those with charging rates of more than 50 TPD, constructed or modified after August 17, 1971. An incinerator is defined as any furnace used to burn solid waste for the purpose of reducing the waste volume by removing combustible matter. Solid waste is defined as refuse, of which more than 50 percent is municipal type waste consisting of a mixture of paper, wood, yard wastes, food wastes, plastics, leather, rubber, and other combustibles, and noncombustible materials such as glass and rock. A day is defined as 24 hours. Because of their small size (less than 50 TPD), most modular incinerators will be regulated by state particulate emission standards.

State Regulations

Table 1 contains particulate emission limitations for states with existing or programmed DA HRIs. State regulations for incinerator particulate emissions are generally more lenient than the Federal regulations for units with less than 50 TPD charging capacity.

The State of Washington also regulates the emission of carbonyl groups from incinerators. Carbonyl groups are partially oxidized carbon compounds. A large amount of carbonyl groups in the flue gas is indicative of poor combustion. Washington has a maximum emission limit of 100 ppm for total carbonyls.

Some state air pollution regulations are based on the characteristics of the wastes incinerated. The states generally define the wastes according to IIA incinerator standards. The IIA groups waste characteristics into seven categories (Table 2). To further identify waste characteristics of Army installations, Army building types were grouped based on their waste production, according to the IIA classifications. Table 3 lists the buildings considered under each waste category.

The most common recording unit for particulate emissions is grains per dry standard cubic foot of flue gas (gr/dscf) corrected to 12 percent carbon dioxide. Other recording units for these selected states are lb/100 lb, lb/hr, lb/MBtu input, and gr/dscf corrected to 7 percent oxygen. Table 1 shows equivalent emission limits in gr/dscf corrected to 12 percent CO_2 for these other units, in order to provide a consistent baseline for comparison to incinerator emission estimates and regulations. Equivalent emissions are based on the IIA conversion factors given in Table 4. Equivalent emissions for wood-fired HRIs were calculated using the IIA type 0 waste category. Emission standards that did not specify a waste type were assumed to have a waste composition of 50 percent Type 1 and 50 percent Type 2. This approximates the waste characteristics found at current Army HRI facilities.

The most common regulation for incinerators with a design capacity of 50 TPD or less is 0.10 gr/dscf corrected to 12 percent CO_2. These emission limits should be considered minimum requirements, since additional limits could be imposed by local city or county pollution control agencies and by state agencies for areas of nonattainment.

Generally, the flexibility of regulatory agencies depends greatly on the attainment status of the air quality in the area where the HRI facility is located. Regulatory agencies will be far more stringent in their air pollution control requirements when an HRI facility is located in an area that is not in compliance with the National Ambient Air Quality Standard for Total Suspended Particulates. Table 5 shows the current attainment status of regions where there are planned HRI facilities.

There are four categories of attainment. The first, and by far the most significant, is "does not meet primary standards." This means the area has not met the 31 December 1982 Congressional deadline for ambient air quality for particulates. In most cases, the state in which the area is located is in danger of losing Federal highway funds until the area attains the required air quality. States take a very dim view of any activity that will add to their attainment problems. The second category is "does not meet secondary standards." This means the area has not met the secondary NAAQS for particulates. The deadline for meeting this standard is 31 December 1986, so the state has a little more flexibility. The third category is "cannot be classified." This means that the state and

Table 1

State Particulate Matter Regulations

State	Emission limit (EL)	Application	Common regulation gr/dscf at 12% CO_2
AL	0.20 lb/100 lb	≤ 50 TPD	0.16
	0.10 lb/100 lb	> 50 TPD	0.08
	Variable (1) 0.48 lb/MBtu 0.35 lb/MBtu	heat-recovery units @ 25 TPD @ 50 TPD	 0.21 0.15
GA	0.10 gr/dscf @ 12% CO_2	After 01-01-72 ≤ 50 TPD	0.10
	0.20 gr/dscf @ 12% CO_2	After 01-01-72 ≤ 50 TPD waste type 3-6	0.20
	0.08 gr/dscf @ 12% CO_2	After 01-01-72 50 TPD	0.08
	0.50 lb/MBtu input	After 01-01-72 heat-recovery units < 10 MBtu input	
GA	Variable (2) 0.47 lb/MBtu 0.33 lb/MBtu	After 01-01-72 heat-recovery units 10 to 250 MBtu input @ 25 TPD @ 50 TPD	 0.20 0.14
	0.10 lb/MBtu input	After 01-01-72 heat-recovery units > 250 MBtu input	
KS	0.30 gr/dscf @ 12% CO_2	< 200 lb/hr	0.30
	0.20 gr/dscf @ 12% CO_2	200 lb/hr & ≤ 20,000 lb/hr	0.20
	0.10 gr/dscf @ 12% CO_2	> 20,000 lb/hr	0.10

(1) EL(lb/MBtu) = $1.38 \times (\text{heat input in MBtu/hr})^{-0.44}$

(2) EL(lb/MBtu) = $0.5 \times (10/\text{heat input in MBtu/hr})^{0.5}$

Table 1 (Cont'd)

State	Emission limit (EL)	Application	Common regulation gr/dscf at 12% CO_2
KY	0.10 gr/dscf @ 12% CO_2	On or after 06-06-79 >= 500 lb/hr & <= 50 TPD	0.10
	0.08 gr/dscf @ 12% CO_2	> 50 TPD	0.08
MA	0.05 gr/dscf @ 12% CO_2	After 06-01-72 All municipal and others >= 50 TPD	0.05
	0.10 gr/dscf @ 12% CO_2	After 06-01-72 Commercial, Industrial < 50 TPD	0.10
MO	0.20 gr/dscf @ 12% CO_2	>= 200 lb/hr Refuse burning	0.20
	0.30 gr/dscf @ 12% CO_2	All others	0.30
NJ	0.20 gr/dscf @ 12% CO_2	<= 2000 lb/hr waste type 0-3	0.20
	0.10 gr/dscf @ 12% CO_2	All others	0.10
NC	Variable (3)		
	0.20 lb/hr	0-100 lb/hr	0.16
	0.40 lb/hr	200 lb/hr	0.16
	1.00 lb/hr	500 lb/hr	0.16
	2.00 lb/hr	1000 lb/hr	0.16
	4.00 lb/hr	>= 2000 lb/hr	0.16
	Variable (4)	Heat-recovery units	
	0.60 lb/MBtu	0-10 MBtu/hr	0.26
	0.33 lb/MBtu	100 MBtu/hr	0.14
	0.18 lb/MBtu	1000 MBtu/hr	0.08
	0.10 lb/MBtu	>=10,000 MBtu/hr	0.04
	Variable (5)	Heat-recovery units (wood-fired only)	
	0.70 lb/MBtu	0-10 MBtu/hr	0.32
	0.41 lb/MBtu	100 MBtu/hr	0.19
	0.25 lb/MBtu	1000 MBtu/hr	0.12
	0.15 lb/MBtu	>=10,000 MBtu/hr	0.07

(3) EL(lb/hr) = 0.002 x heat input (lb/hr)

(4) EL(lb/MBtu) = 1.090 x (heat input in MBtu/hr) $^{-0.2594}$

(5) EL(lb/MBtu) = 1.1698 x (heat input in MBtu/hr) $^{-0.2230}$

Table 1 (Cont'd)

State	Emission limit (EL)	Application	Common regulation gr/dscf at 12% CO_2
NC	Variable (6) (combination of wood and other fuels)	Heat-recovery units	
	0.37 lb/MBtu municipal waste @ 50 TPD	50% wood and 50%	0.17
OK	Variable (7)		
	0.68 lb/hr	200 lb/hr	0.27
	3.87 lb/hr	2000 lb/hr	0.16
	6.75 lb/hr	50 TPD	0.13
PA	0.10 gr/dscf @ 12% CO_2	All	0.10
SC	0.50 lb/MBtu input	All	0.22
UT	Case-by-case basis	$\leq$ 50 TPD	----
	0.08 gr/dscf @ 12% CO_2	$\geq$ 50 TPD	0.08
VA	0.14 gr/dscf @ 12% CO_2	All	0.14
WA	0.10 gr/dscf @ 7% O_2	All	0.10
	0.20 gr/dscf @ 7% O_2 for steam production	Wood burning	0.20

(6) EL(lb/MBtu) = [EL(wood) x heat input(wood) + EL(fuel) x heat input(fuel)] / total fuel input

(7) EL(lb/hr) = 0.012221 x heat input(lb/hr) $^{0.07577}$

Table 2

IIA Waste Classifications
(From *I. I. A. Incinerator Standards* [Incinerator Institute of America, 1968].)

Classification of Wastes to Be Incinerated

Classification of wastes Type/Description	Principle components	Approximate composition % by weight	Measure content %	Incombustible solids %	Btu value/lb of refuse as fired	Btu of aux fuel per lb of waste to be included in combustion calculations	Recommended min Btu/hr burner input per lb waste
*0/Trash	Highly combustible waste, paper, wood, cardboard cartons, including up to 10 % treated papers, plastic or rubber scraps; commercial and industrial sources	Trash 100	10	5	8500	0	0
*1/Rubbish	Combustible waste, paper, cartons, rags wood scraps, combustible or sweepings; domestic, commercial, and industrial sources	Rubbish 80 Garbage 20	25	10	6500	0	0
*2/Refuse	Rubbish and garbage; residential sources	Rubbish 50 Garbage 50	7	4300	0	1500	
*3/Garbage	Animal and vegetable wastes, restaurants hotels, markets; institutional, commercial, and club sources	Garbage 65 Rubbish 35	70	5	2500	1500	3000

Table 2 (cont'd)

Classification of Wastes to Be Incinerated

Classification of wastes Type/Description	Principle components	Approximate composition % by weight	Measure content %	Incombustible solids %	Btu value/lb of refuse as fired	Btu of aux fuel per lb of waste to be included in combustion calculations	Recommended min Btu/hr burner input per lb waste
*4. Animal solids and organic wastes	Carcasses, organs solid organic wastes; hospital, laboratory, abattoirs, animal pounds, and similar sources	Animals and Human Tissue 100	85	5	1000 (5000 Primary) (3000 Secondary)	3000	8000
5. Gaseous liquid or semi-liquid wastes	Industrial process wastes	Variable on predominant components	Dependent according to wastes survey	Variable according to wastes survey	Variable according to wastes survey	Variable according to wastes survey	Variable
6. Semi-solid and solid wastes	Combustibles requiring health, retort, or grate burning equipment	Variable	Dependent on predominant components	Variable according to wastes survey	Variable according to wastes survey	Variable according to wastes survey	Variable according to wastes survey

Table 3

Classification of Waste Sources

IIA Classification	Building types
Type 0	Offices, business establishments, classrooms, material storage, maintenance areas, community facilities, and firing ranges
Type 1	Commissaries, hospitals, laundry and dry cleaning plants, barracks without mess, fire and police stations
Type 2	Family housing, barracks with mess, dependent schools, stockades
Type 3	Messhalls (including snack bars and cafeterias), clubs, meat-cutting plants, and bakeries
Type 4	Hospitals, kennels, biological laboratories
Type 5	Water treatment plants, sewage treatment plants, industrial waste treatment plants
Type 6	Power and heat generation plants, refuse incinerators

Table 4

IIA Particulate Emission Conversion Factors*
(From *I.I. A. Incinerator Standards* [Incinerator Institute of America, 1968].)

Grains**	per standard cu ft***	x 1.87	= lb per 1000 lb of flue gas
	per standard cu ft	x 2.20	= lb per 1,000,000 Btu input
	per cu ft of 500°F flue gas	x 3.45	= lb per 1000 lb of flue gas
Pounds	per 1000 lb of flue gas	x 0.53	= grains per standard cu ft
	per 1000 lb of flue gas	x 0.29	= grains per cu ft of 500°F flue gas
	per 1000 lb of flue gas	x 1.18	= lb per 1,000,000 Btu input
Pounds	per 1,000,000 Btu input	x 0.45	= grains per standard cu ft
	per 1,000,000 Btu input	x 0.85	= lb per 1000 lb of flue gas
Pounds	per 100 lb of Type 0 Waste	x 1.01	= lb per 1000 lb of flue gas
	per 100 lb of Type 1 Waste	x 1.30	= lb per 1000 lb of flue gas
	per 100 lb of Type 2 Waste	x 1.84	= lb per 1000 lb of flue gas
	per 100 lb of Type 3 Waste	x 2.80	= lb per 1000 lb of flue gas
Pounds	per 100 lb of Type 0 Waste	x 0.54	= grains per standard cu ft
	per 100 lb of Type 1 Waste	x 0.70	= grains per standard cu ft
	per 100 lb of Type 2 Waste	x 0.90	= grains per standard cu ft
	per 100 lb of Type 3 Waste	x 1.50	= grains per standard cu ft
Pounds of flue gas per hour		x 0.22	= standard cu ft per minute
Standard cu ft per minute		x 4.50	= lb of flue gas per hour

*All factors are based on properties of flue gas approaching those of dry air. For ease of calculations any small differences are ignored, and "corrected to 50 percent excess air" and "corrected to 12 percent CO_2" are considered equal.

**Grains is a measure of weight; 7000 grains = 1 lb. In these Standards, all expressions of particulate emissions (dust loadings) are given with the total flue gases (products of combustion) corrected to 50 percent excess air.

***Standard cu ft is air at 70°F and 29.92 in. of mercury.

Table 5

State NAAQS Attainment Status for TSP

Installation	Attainment status
Fort Benning	
Area: Russell, AL	Better than national standards
Area: Chattahoochee, GA	Better than national standards
Fort Bragg	
Area: Cumberland, NC	Better than national standards
Area: Hoke, NC	Better than national standards
Fort Campbell	
Area: Montgomery, TN	Better than national standards
Area: Stewart, TN	Better than national standards
Fort Devens	
Area: Middlesex, MA	Better than national standards
Except: Cities of Cambridge, Medford and Waltham	Does not meet secondary standards
Except: Town of Framingham	Does not meet secondary standards
Except: Cities of Everett, Malden, Marlborough, Melrose, Newton, and Somerville and Towns of Wakefield, Watertown, Wayland, Weston, Winchester, Arlington, Belmont, Braintree, Natick, and Stoneham	Cannot be classified
Area: Worcester, MA	Better than national standards
Except: City of Worcester	Does not meet primary standards
Except: City of Athol	Does not meet secondary standards
Except: Cities of Gardner and Leominster and Towns of Grafton, Millbury, Shrewsbury, and Southborough	Cannot be classified
Fort Dix	
Area: Burlington, NJ	Better than national standards
Area: Ocean, NJ	Better than national standards

Table 5 (Cont'd)

Installation	Attainment status
Fort Eustis	
Area: Charles City, VA	Better than national standards
Area: Gloucester, VA	Better than national standards
Area: Isle of Wight, VA	Better than national standards
Area: James City, VA	Better than national standards
Area: King and Queen, VA	Better than national standards
Area: Mathews, VA	Better than national standards
Area: Middlesex, VA	Better than national standards
Area: New Kent, VA	Better than national standards
Area: Prince George, VA	Better than national standards
Area: Southampton, VA	Better than national standards
Area: Surry, VA	Better than national standards
Area: Sussex, VA	Cannot be classified
Area: York, VA	Better than national standards
Area: Chesapeake City, VA	Cannot be classified
Area: Hampton City, VA	Better than national standards
Area: Newport News City, VA	Better than national standards
Area: Norfolk City, VA	Better than national standards
Area: Portsmouth City, VA	Better than national standards
Area: Williamsburg City, VA	Better than national standards
Fort Gordon	
Area: Columbia, GA	Better than national standards
Area: Jefferson, GA	Better than national standards
Area: McDuffie, GA	Better than national standards
Fort Knox	
Area: Bullitt, KY	Better than national standards
Except: One portion of Shepherdsville	Does not meet primary standards
Area: Hardin, KY	Better than national standards
Area: Meade, KY	Better than national standards
Fort Lee	
Area: Prince George, VA	Better than national standards

Table 5 (Cont'd)

Installation	Attainment status
Fort Lewis	
Area: Pierce, WA	Better than national standards
Area: Thurston, WA	Better than national standards
Fort McClellan	
Area: Calhoun, AL	Better than national standards
Redstone Arsenal	
Area: Madison, AL	Better than national standards
Fort Riley	
Area: Geary, KS	Better than national standards
Area: Riley, KS	Better than national standards
Fort Rucker	
Area: Coffee, AL	Better than national standards
Area: Dale, AL	Better than national standards
Fort Sill	
Area: Comanche, OK	Better than national standards
Except: Portions of Comanche County	Cannot be classified
Fort Stewart	
Area: Bryan, GA	Better than national standards
Area: Evans, GA	Better than national standards
Area: Liberty, GA	Better than national standards
Area: Long, GA	Better than national standards
Area: Tattnall, GA	Better than national standards
Tooele Army Depot	
Area: Tooele, UT	Better than national standards
Fort Leonard Wood	
Area: Laclede, MO	Better than national standards
Area: Pulaski, MO	Better than national standards

the USEPA cannot agree on the attainment status of the region. In these regions, an HRI facility planner is best advised to find out if attainment of primary or secondary standards is in question. This can best be answered by the state or by the local air pollution regulatory agency having jurisdiction over the region. The final category is "better than national standards." This means the region is in compliance with both the primary and secondary NAAQS for particulates. Here, the state has the most flexibility in working with the proposed HRI facility.

Visibility Regulations

The USEPA method for determining visible emissions is contained in CFR, Part 40, Title 40, Chapter 1, Appendix A, "Method 9 - Visual Determination of the Opacity of Emissions From Stationary Sources and Alternate Method 1--Determination of the Opacity of Emissions From Stationary Sources Remotely by Lidar*." The USEPA does not currently use in-stack opacity monitors as an enforcement technique, although some states may require their use for compliance purposes. The most common enforcement method is for a qualified observer to determine opacity. Many states also use the Ringelmann Method published in the U.S. Bureau of Mines Circular 7718. The Ringelmann Method is also given in the *Annual Book of ASTM Standards*, ASTM D 3211.

Table 6 lists regulations that limit the visible plume for incinerators. Emission limits are given in terms of percent opacity or Ringelmann chart number. The Ringelmann method can be expressed as percent opacity by multiplying the Ringelmann number by 20. For example, a Ringelmann number 1 is equal to 20 percent opacity. Typical visibility limits are 20 percent opacity or number 1 on the Ringelmann chart. Most state emission limits provide less stringent limits during start-up, shut-down, and soot blowing. Limits for these times are typically greater than 40 percent opacity or number 2 Ringelmann for 3 to 6 minutes per hour. The effect of water vapor on plume visibility is usually disregarded.

Hazardous Emission Regulations

CFR, Title 40, Chapter I, Part 61, contains Federal regulations that limit hazardous emissions. Only the standard limiting beryllium emissions pertains directly to incinerators. The Federal regulation limiting beryllium emissions from incinerators is contained in CFR, Title 40, Chapter I, Part 61, Subpart C, "National Emission Standard for Beryllium." This regulation limits beryllium emissions to less than 10 g per 24-hour period.

Beryllium is an alloying agent used in the production of beryllium copper. Waste sources of beryllium copper are springs, electrical contacts, welding electrodes, motor windings, computer components, and electrical components. Beryllium is also used in the structural material of high-speed aircraft, missiles, and spacecraft. Beryllium emissions from municipal incinerators should not be large enough to be of concern, although little emissions data has been compiled.

Most state air quality regulations contain a catchall regulation that restricts the emission of any hazardous or toxic pollutants. The states will determine the extent of

*Lidar is an acronymn for Light Detection and Ranging--a laser radar system used in remote sensing applications.

Table 6

State Opacity Regulations

State	Emission limit	Application
AL	20% opacity	All
	40% opacity for 6 min/60 min	All
GA	< 20% opacity	After 01-01-72
	27% opacity for 6 min/hr	Heat-recovery units
KS	< 20% opacity	All
KY	20% opacity	All
MA	20% opacity	All
	<= 100 micron particles	All
MO*	<#1 Ringelmann	New incinerators
	<#1 Ringelmann	After 01-01-73, Tepee burners
	<#2 Ringelmann	All others
	> #2 Ringelmann for 6 min/60 min	All others
	> #2 Ringelmann (40% opacity) for 30 min	Tepee burners
MO	< #1 Ringelmann (20% opacity)	All
	#2 Ringelmann (40% opacity) for 6 min/60 min	All
NJ	#1 Ringelmann	All
	#2 Ringelmann for new fire	All
	> #2 Ringelmann for < 3 min	All

*Except the cities of St. Louis and St. Charles and the counties of St. Charles, St. Louis, Jefferson, Franklin, Clay, Cass, Buchanan, Ray, Jackson, Platte, and Greene.

Table 6 (cont'd)

State	Emission limit	Application
NC	> #1 Ringelmann or 20% opacity for 5 min/hr or 20 min/24 hr	After 7-1-72
OK	#1 Ringelmann (20% opacity)	All
	#3 Ringelmann for 5 min/60 min or 20 min/24 hr	All
PA	20% - < 60% opacity for 3 min/60 min	All
	< 60% opacity	All
SC	> 20% opacity for 6 min/60 min or 24 min/24 hr	All
UT	20% opacity	All
	> 20% opacity for 3 min	All
VA	20% opacity	All
	> 20% - 60 % opacity for 6 min/60 min	All
WA	> 20% opacity for 3 min/60 min	All
	> 20% opacity for 15 min/8 hr	For soot blowing and grate cleaning

controls needed on a case-by-case basis. Hazardous and toxic air pollutant regulations for incinerators have emphasized primarily facilities that burn industrial process wastes. Municipal type waste facilities have been scrutinized primarily when the waste contains a high percentage of chloride-containing plastics.

Emission Regulation Trends

As new research is conducted and states continually strive to meet their SIP requirements, environmental regulations will be subject to change at both the State and Federal levels. To help assess environmental regulations, the U.S. Army Construction Engineering Research Laboratory (USA-CERL) developed the Computer-Aided Environmental Legislative Data System (CELDS).[2] CELDS is a subsystem of ETIS, a computer system that helps military planners prepare environmental impact assessments and environmental impact statements. CELDS and the rest of ETIS may be used via remote terminals or with the aid of USA-CERL personnel. The system is designed for the layperson, with easy-to-understand commands and prompts. CELDS contains a continuously updated database of current Federal and State environmental regulations. The regulations are abstracted to make them easier to read and understand. CELDS is not intended to replace the actual regulation, but to provide quick access to and easy interpretation of current legislation that may have an impact on Army programs. CELDS can provide current environmental regulations, but does not provide information on proposed regulations. This information must be obtained from USEPA research and publications.

New Source Performance Standard

The USEPA has proposed a New Source Performance Standard (NSPS) for industrial-sized boilers. The proposed standard would limit emissions of particulate matter from new, modified, and reconstructed industrial boilers capable of burning more than 29 MW (100 million Btu/hour) and less than 73 MW (250 million Btu/hour) heat input. Boilers burning coal, oil, natural gas, wood, and solid waste would be regulated. This standard would limit particulate matter emissions to 43 ng/J (0.10 lb/million Btu) input and opacity to 20 percent. The opacity standard would not apply to boilers using wet scrubber air pollution control devices. The proposed standard would be much more stringent than current state standards. Communications with USEPA[3] suggest that this proposed NSPS was not intended to regulate small municipal waste units such as the 20 to 50 TPD modular units, even if a modular incinerator facility with heat recovery had a combined heat input that would meet or exceed the 29-MW threshold.

National Ambient Air Quality Standard

Another proposed standard that may affect incinerator emission standards is the 10-micron ambient particulate National Ambient Air Quality Standard. Although this standard would not enforce an emission limit, it would be incorporated in the SIPs, which would then have to develop a strategy to achieve and maintain the new standard. Part of the strategy would probably be to set emission limits on particulate matter sources.

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[2] van Weringh, J., et al., *Computer-Aided Environmental Legislative Data System (CELDS) User Manual*, Technical Report N-56/ADA061126 (USA-CERL, 1978).

[3] Personal Communication between Martin Savoie (USA-CERL) and Charles Sedman (USEPA Office of Air Quality Planning and Standards, Research Triangle Park, NC).

Particulate Size

There are few particulate size data for modular incinerators from which a standard might be developed, although a study performed on a municipal Consumat system in North Little Rock, AR, and an industrial Kelley system in Marysville, OH, has indicated the particle size range that could be expected for these modular incinerator types. Ninety percent of the Consumat system particulate emissions, by weight, were less than 7 microns in diameter[4] and 85 percent of the Kelley system particulate emissions, by weight, were less than 7 microns in diameter. With such a high percentage of particulate emissions under 10 microns, modular incinerators may be regulated more carefully in the future.

Chlorides

Chloride emissions from incineration have recently become a concern to environmental and health agencies. These emissions originate from the combustion of chlorinated plastics, especially polyvinyl chloride (PVC). The Occupational Safety and Health Administration regulates workplace concentrations of hydrogen chloride to 5 ppm maximum. Chloride emissions from incinerators are not currently regulated by the USEPA or any state agency; however, several states are considering such regulations. For resource recovery facilities, the New Jersey Department of Environmental Protection recommends 90 percent hydrogen chloride (HCl) control efficiency or 50 ppm (volume) HCl emission limit from the stack.

Little data is available to develop an emission estimate for chloride emissions from small incinerators. This study identified three incinerator facilities, representative of modular incinerators, that had recorded chloride stack emissions. A 25-TPD modular incinerator with heat recovery that burns municipal waste, located in Little Rock, AR, reported chloride emissions of 130 ppm. The average daily plastics content was 8.7 percent, by weight, of the waste burned. A 20-TPD modular incinerator with heat recovery that burns municipal wastes, located at Fort Eustis, VA, reported emissions of 169.5 ppm HCl. The waste burned included PVC trash bags that contained leaves. In Marysville, OH, a 12-TPD modular industrial incinerator with heat recovery that burns wood and paper wastes reported chloride emissions of 54 ppm. The average daily plastics content was less than 0.1 percent of the waste burned.

Future regulations may require emissions from incinerators other than particulates to be reduced and may require additional air pollution control equipment. However, particulates are currently the most regulated and the most documented incinerator pollutant. Alternatives to air pollution control equipment may be reducing the amount or type of plastics in the waste stream or maintaining high temperatures in the secondary combustion chamber.

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[4] Frounfelker, R. E., and N. J. Kleinhenz, "A Technical Evaluation of Modular Incinerators with Heat Recovery," *Journal of Energy Resources Technology*, Vol 103 (December 1981), pp 265-269.

4 INCINERATOR PARTICULATE EMISSIONS

Modular incinerator emissions data were obtained from selected manufacturers listed in the *Thomas Register* and from other published literature. Table 7 lists incinerator manufacturers contacted for emissions information. Federal and State agencies were contacted for incinerator emissions data, but none of them appear to include small incinerator sources in their emissions inventory systems.

Table 8 summarizes particulate matter emissions from modular incinerators; incinerator units are listed by manufacturer and grouped by incinerator type. Where possible, emission rates are given in gr/dscf corrected to 12 percent CO_2, since this was the most common unit for particulate emission regulations. Also listed for each source are the charge rate and the waste type burned.

The most common modular incinerators appear to be starved-air units, but this summary does not include all incinerators or incinerator manufacturers. The starved-air incinerators listed have a range of 0.032 to 0.212 gr/dscf corrected to 12 percent CO_2 for Type 1 and Type 2 wastes, with an average of 0.1 gr/dscf corrected to 12 percent CO_2. The starved-air units have a range of 0.049 to 0.092 gr/dscf, with an average of 0.058 gr/dscf for the wood and paper components of these wastes.

Emission rates for the reciprocating-grate units listed ranged from 0.0456 to 0.55 gr/dscf corrected to 12 percent CO_2 for municipal wastes. These units are much larger than any of the units programmed for the Army. A unit burning hospital wastes had an emissions rate of 0.1866 gr/dscf corrected to 12 percent CO_2. All these units operated with air pollution control equipment that included an electrostatic precipitator.

The only augered-bed unit for which data was obtained had a range of 0.2685 to 0.5030 gr/dscf corrected to 12 percent CO_2, for household-type waste. This unit operated with a wet cyclonic separator for air pollution control.

Rotary kiln units listed had a range of 0.013 to 0.033 gr/dscf corrected to 12 percent CO_2 for municipal-type waste. Both units listed operated with air pollution control devices. Two units burning Type 4 waste averaged an emission rate of 0.082 gr/dscf without additional pollution control. Some rotary kiln units are operating close to starved-air conditions, which would reduce the amount of particulates suspended by excess air.

The USEPA has developed emission factors for several categories of incinerators (Table 9). The emission (uncontrolled) factor for starved-air incinerators is 1.4 lb per ton of refuse charged. Using the IIA conversion factors in Table 4 for 50 percent type 1 and 50 percent type 2 waste, the emission factor is about 0.056 gr/dscf corrected to 12 percent CO_2. The emission (uncontrolled) factor for an excess air incinerator is 30 lb per ton of refuse charged. This translates to 1.2 gr/dscf corrected to 12 percent CO_2. These emission factors may be biased because they do not reflect current technology upgrades for either type of incinerator. The emission factors are also based on a large and varied database that does not show individual incinerator performance. Even though the USEPA emission factors may be a rough estimate for small incinerators, it is obvious that starved air incinerators are very capable of meeting state and Federal emission standards without the aid of high technology air pollution control equipment.

The USEPA incinerator pollutant emissions estimation procedure can be difficult and often requires a novice user to supply information about which he/she may be

unsure. To make air pollutant emissions calculations simpler, USA-CERL has developed a standardized procedure that uses the USEPA emission factors for incinerators. The computerized procedure, called BURN, covers several types of incinerators including modular (or controlled-air) HRIs. The BURN model has the advantages of a consistent estimation procedure and of default values for required input data. Once the applicable air pollutant emissions regulations have been identified, the BURN model also enables the user to identify the air pollution control technology applicable to his/her HRI project. The BURN model is accessible through ETIS.

Table 7

Modular Incinerator Vendors Contacted for Product Information

Basic Engineering Inc.
21 W 161 Hill Street
Glen Ellyn, IL 60137
(312)469-5340
Reynaldo C. Familar

Burn-Zol
Division of New Way Industries, Inc.
P.O. Box 8809
Stockton, CA 95208
(209)931-1297
Edward J. Abendschein, President

C-E Raymond
Combustion Engineering, Inc.
200 West Monroe Street
Chicago, IL 60606
Dennis E. Oberg, Regional Sales Manager

Comtro Division
Sunbeam Equipment Corporation
180 Mercer Street
Meadville, PA 16335
(814)724-1456
Edward J. Donley, Project Engineer

Industronics, Inc.
489 Sullivan Avenue
P.O. Box G
South Windsor, CT 06074-0956
(203)289-1551
Barbara C. Klenke

Kelley Company, Inc.
6720 North Teutonia Avenue
Milwaukee, WI 53209
(414)352-1000
Roy D. Miller, Regional Manager

M&S Manufacturing Company, Inc.
95 Rye Street
Broad Brook, CT 06016
(203)627-9396
Zygmunt J. Przewalski

Stock Equipment Company
Energy Systems
16776 Bernardo Center Drive
San Diego, CA 92128
(619)485-9864
Jerry Mills, Project Engineer

ThermAll, Inc.
P.O. Box 1776
Peapack, NJ 07977
(201)234-1776
Mitchel R. Gorski, Jr., Sales Manager

Therm-tec
P.O. Box 1105
11095 S.W. Industrial Way
Tualatin, OR 97062
(503)692-1490

Trofe Incineration, Inc.
Trofe Industrial Park, Pike Road
Mt. Laurel, NJ 08054
(609)235-3030
Henry J. Stein, Director of Marketing

C.E. Industries Corporation
U.S. Smelting Furnace Company
P.O. Box 446
1200 A Street
Belleville, IL 62222
(618)233-0129
Robert B. Hess, President

Wastherm Corporation
Consumat Systems, Inc.
396 E. Church Road
King of Prussia, PA 19406-2694
(215)275-9772
Bob Bickings

Table 8

Modular Incinerator Particulate Emissions

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
<u>Starved-air units</u>			
Basic Engineering Inc. model 2500 Riverdale, IL	0.0268	1.25 TPH	wood pallets
Basic Engineering Inc. Melrose Park, IL	0.05762	3500 lb/hr	wood and paper
Bayco Controlled Air	0.057	not given	not given
Besser-Wasteco model CA300	0.044	344 lb/hr	Type 1
Brule FG4-T-5	*-1	not given	not given
Brule FG4-12 w/flue gas scrubber	*-2	not given	not given
Brule FG4-9(S) w/wet flue gas scrubber	< 0.5	not given	not given
Comtro model A-48 with heat recovery Jacksonville Naval Air Station, FL	0.1072	2285 lb/hr	not given
Comtro model A-50 Douglas Furniture Co. Chicago, IL	0.0665	1 TPH	wood
Consumat C-1000 Pentagon, DC	0.096	2000 lb/hr	Type 0
Consumat C-550M Pahokee, FL	0.0654	1757 lb/hr	Type 2
Consumat C-760M Orlando, FL	0.0843	2889 lb/hr	Type 1

*Uncorrected emission rates
(1) <0.25 lb/hr
(2) 0.065 gr/scf

Table 8 (Cont'd)

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
Starved-air units			
Consumat C-550MS with heat recovery Siloam Springs, AR	0.0302	2435 lb/hr	Type 1
Consumat with heat recovery North Little Rock, AR	0.130	1.9 TPH	Type 2
Consumat model CS-1000 with heat recovery Fort Eustis, VA	0.155	5133 lb/hr	Type 2
Environmental Control Products, Inc.	*-4	502-520 lb/hr	Type 4
Environmental Control Products, Inc.	*-5	1533-1626 lb/hr	Type 4
Environmental Control Products, Inc.	*-6	500 lb/hr	Type 1
Environmental Control Products model 2500-T with heat recovery Fort Leonard Wood, MO	0.1300	1 TPH	Type 2
Kelley Co. model 1280 Milwaukee, WI	0.039	100 lb/5 min	USPHS test charge **
Kelley Co. model 1280 Meredith, NH	0.163	1071 lb/hr	Type 2
Kelley Co. model 1280/72 Rocky Hill, CT	0.073	1373 lb/hr	Type 0 & 1

*Uncorrected emission rates
(4) 0.0088 to 0.01 gr/cu ft at stack conditions
(5) 0.0159 to 0.02 gr/cu ft at stack conditions
(6) 0.0092 to 0.0099 gr/cu ft at stack conditions
**HEW and USPHS test waste composition.

Table 8 (Cont'd)

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
Starved-air units			
Kelley Co. model 1280/72 Portland, OR	0.092	20,000 lb/day	95% card-board
Kelley Co. model 780 Elk Grove Village, IL	0.063	715 lb/hr	Type 4
Kelley Co. 12 TPD unit Marysville, OH	0.049	600 lb/hr	wood and paper
Kelley Co. model 780 Milwaukee, WI	0.0412	800 lb/hr	HEW test waste *
Midland-Ross Mark VI Radicator Los Angeles, CA	0.089 to 0.203	445 lb/hr	Type 0
Midland-Ross Mark VI Radicator Phoenix, AZ	**-7	445 lb/hr	Type 0
	**-8	625 lb/hr	Type 1
	**-9	795 lb/hr	Type 2

*HEW and USPHS test waste composition
23 percent corrugated cardboard, shredded into 1/2-in. strips
22 percent newspaper, cut into 2 x 12 inch strips
17 percent magazines, cut into 2 x 12 inch pieces
5 percent brown paper, shredded
5 percent wax-coated paper, shredded
5 percent plastic-coated paper, shredded
23 percent raw potatoes, cut into about 1/2- x 1/2- x 3-in. strips

**Uncorrected emission rates
(7) 0.036 to 0.125 lb/1000 lb gas
(8) 0.024 to 0.077 lb/1000 lb gas
(9) 0.048 to 0.067 lb/1000 lb gas

Table 8 (Cont'd)

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
<u>Starved-air units</u>			
Midland-Ross Mark VI Radicator San Francisco, CA	*-10	445 lb/hr	Type 0
	*-11	625 lb/hr	Type 1
	*-12	795 lb/hr	Type 2
Midland-Ross Mark VI Radicator Denver, CO	*-13	445 lb/hr	Type 0
	*-14	625 lb/hr	Type 1
	*-15	795 lb/hr	Type 2
Midland-Ross Mark VI Radicator Los Angeles, CA	0.062 to 0.169	625 lb/hr	Type 1
Midland-Ross Mark VI Radicator Los Angeles, CA	0.212	795 lb/hr	Type 2
Smokatrol, Inc. Model 200 Geenville, SC	*-16	200 lb/hr	Type 1
<u>Reciprocating-grate units</u>			
Clear Air with water scrubber and electrostatic precipitator	0.55	281 TPD	Type 2

*Uncorrected emission rates
(10) 0.05 to 0.136 gr/scf
(11) 0.034 to 0.076 gr/scf
(12) 0.074 to 0.089 gr/scf
(13) 0.04 to 0.13 lb/1000 lb gas corrected to 50 percent air
(14) 0.02 to 0.07 lb/1000 lb gas corrected to 50 percent air
(15) 0.05 to 0.07 lb/1000 lb gas corrected to 50 percent air
(16) 0.02 gr/dscf at stack conditions

Table 8 (Cont'd)

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
Reciprocating-grate units			
Clear Air with water curtain scrubber and electrostatic precipitator Weber County, UT	0.0456	6.63 TPH	Type 2
Clear Air with electrostatic precipitator Hamilton, MT	0.1866	17 TPD	Type 4
Augered-bed units			
Hoskinson and Assoc. Hoskinson auger combustor with wet cyclonic separators Jacksonville, FL	0.2685 to 0.5030	5 TPH	Type 2
Rotary-kiln units			
Thermall Inc. Rotary kiln with heat recovery and baghouse	0.0330	not given	Type 2
Trofe Incineration, Inc. Mt. Laurel, NJ, with air pollution control	0.013	not given	not given
Industronics, Inc. Baltimore, MD	0.087	400 lb/hr	Type 4
Industronics, Inc. South Windsor, CN	0.023	305 lb/hr	cardboard
Industronics, Inc. South Windsor, CN	0.076	249 lb/hr	Type 4
Industronics, Inc. with baghouse South Windsor, CN	0.006	220 lb/hr	paper

Table 8 (Cont'd)

Unit type/Location	Emissions gr/dscf at 12% CO_2	Charge rate	Waste type
Rotary kiln units			
Industronics, Inc South Windsor, CN	*-17	300 lb/hr	Type 1
Industronics, Inc South Windsor, CN	*-18	360 lb/hr	Type 2

*Uncorrected emissions
(17) 0.031 gr/dscf
(18) 0.03 gr/dscf

Table 9

USEPA Incinerator Emission Factors*
(From *Compilation of Air Pollutant Emission Factors*, including Supplements 1-12, third edition, USEPA Office of Air Quality Planning and Standards, 1977].)

Incinerator type	Particulates lb/ton	Particulates kg/MT	Sulfar oxides** lb/ton	Sulfar oxides** kg/MT	Carbon monoxide lb/ton	Carbon monoxide kg/MT	Organics*** lb/ton	Organics*** kg/MT	Nitrogen oxides+ lb/ton	Nitrogen oxides+ kg/MT
Municipal										
Multiple chamber, uncontrolled	30	15	2.5	1.25	35	17.5	1.5	0.75	3	1.5
With settling chamber and water spray system++	14	7	2.5	1.25	35	17.5	1.5	0.75	3	1.5
Industrial/commercial										
Multiple chamber	7	3.5	2.5+++	1.25	10	5	3	1.5	3	1.5
Single chamber	15	7.5	2.5+++	1.25	20	10	15	7.5	2	1
Trench										
Wood	13	6.5	0.1+	0.05	NA	NA	NA	NA	4	2
Rubber Tires	138	69	NA	NA	NA	NA	NA	NA	NA	NA
Municipal refuse	37	18.5	2.5+++	1.25	NA	NA	NA	NA	NA	

*Average factors given based on EPA procedures for incinerator stack testing.
**Expressed as sulfur dioxide.
***Expresses as methane.
+Expressed as nitrogen dioxide.
++Most municipal incinerators are equipped with at least this much control: See Table 2-1-1 for appropriate efficiencies for other controls.
+++Based on municipal incinerator data.
+ Based on data for wood combustion in conical burners.

Table 9 (cont'd)

Incinerator type	Particulates		Sulfar oxides**		Carbon monoxide		Organics***		Nitrogen oxides+	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Controlled air	1.4	0.7	1.5	0.75	Neg	Neg	Neg	Neg	10	5
Flue-fed single chamber	30	15	0.5	0.25	20	10	15	7.5	3	1.5
Flue-fed (modified)**	6	3	0.5	0.25	10	5	3	1.5	10	5
Domestic single chamber										
Without primary burner	35	17.5	0.5	0.25	300	150	100	50	1	0.5
With primary burner	7	3.5	0.5	0.25	Neg	Neg	2	1	2	1
Pathological	8	4	Neg	Neg	Neg	Neg	Neg	Neg	3	1.5

** With afterburners and draft controls.

5 AIR POLLUTION CONTROL EQUIPMENT

Emissions data for modular incinerators show that many models can meet State air pollution standards without the aid of air pollution control devices. One reason for this is the use of a high-temperature afterburner in the secondary chamber. The afterburner performs as an air pollution control device by destroying unburned carbon compounds. When controls were used, they occurred most frequently on excess-air and rotary kiln units. Starved-air units required the least amount of control.

The amount of air pollution control required for an incinerator may be estimated from the appropriate emission regulations and pollutant emission estimates for the incinerator. If the incinerator emissions exceed the emission regulation, the excess emissions must be controlled. Knowing the amount of emission reduction needed, the pollution control equipment can be selected based on the efficiency of the control device as shown in Table 10. Other factors are necessary in the final sizing and choice of a pollution control device, but identifying the percent removal needed is the first step.

The primary pollutant to be controlled from incinerators is particulates. The three major particulate control techniques for modular incinerators are mechanical collection with cyclones, filtration with baghouses, and electrostatic precipitation (ESP). Wet scrubbers may also be used to control particulate emissions, but are primarily used to control gaseous emissions, such as chlorides. Most of the modular incinerators identified in this report that used air pollution controls were excess-air and rotary-kiln units.

If an expensive air pollution control technology such as scrubbers, fabric filters, or electrostatic precipitators is required, the project planner should consider using Emissions Trading Procedures (ETP). These are techniques that can be used to reduce the degree of control required on HRIs. If the proposed project is located in a region that has already attained the NAAQS for particulates, it may be possible to control particulate emissions from other air pollutant sources on the installation and trade them for particulate emissions from the HRI facility. The two procedures most likely to be used with HRIs are Bubble Policy and Emissions Banking. These ETP techniques are always used with a lower-cost particulate control procedure such as mechanical collectors. The USA-CERL Environmental Division can provide further information or assistance in using ETP techniques on HRI facilities.

Table 10

Incinerator Particulate Control Device Efficiency
(From *Compilation of Air Pollutant Emission Factors*, including Supplements 1-12, third edition [USEPA, Office of Air Quality Planning and Standards] 1977.)

Type of System	Efficiency, %
Settling chamber	0 to 30
Settling chamber and water spray	30 to 60
Wetted baffles	60
Mechanical collector	30 to 80
Scrubber	80 to 95
Electrostatic precipitator	90 to 96
Fabric filter	97 to 99

The following sections discuss the fundamental principles and operations of cyclones, baghouses, and ESPs.

Cyclones

Cyclones are dry, mechanical, particulate separation devices that use inertial separation to remove particulate matter from flue gases. Cyclones can be used on solid-fuel-fired boilers and on solid waste incinerators. Because of their relatively low removal efficiency, they are normally used as primary collectors, enabling downstream collectors such as electrostatic precipitators, fabric filters, and scrubbers to operate more efficiently.

Figure 10 illustrates the common principle of operation for two configurations of cyclones. Particulate-laden gas is drawn tangentially into a cylindrical or conical chamber and, spiraling upward, exits through a central opening. The outer vortex motion creates a strong centrifugal force field in which the particles, through their inertia, separate from the carrier gas stream. Separated particles migrate along the walls by gas flow and gravity and fall into a storage hopper. Special high-efficiency cyclones include a disengaging chamber for spinout in the lower portion of the equipment. The flyash may be reinjected into the combustor, depending on the amount of its combustible content. Pressure drops through medium-efficiency cyclones range from 0.5 to 4 in. water, and are up to 20 percent higher for high-efficiency units. Gas velocity rarely exceeds 4000 ft/min.

Cyclones have the advantages of simple construction, low first and recurring costs, relative insensitivity to ash properties and sudden flow rate changes, acceptable turndown ratio, and ease of retrofit because of their comparatively small size and low weight. Disadvantages include low particle collection efficiency, susceptibility to erosion by abrasive particles, and reduced performance caused by buildup of agglomerating particulates.

Medium-efficiency cyclones are suitable for separating particulates in the 15 to 40-micron size range, but are not suitable for fine dusts and fumes. High-efficiency cyclones can sometimes remove as much as 60 percent of 3-micron and 80 to 90 percent of 5-micron particulates. Because of their relatively low efficiency, cyclones are used in boiler and incinerator plants to remove large, coarse, abrasive particles that could damage downstream fabric filters, and to improve electrostatic precipitator and scrubber efficiency by allowing a more uniform inlet flow.

Cyclones are highly reliable, partly because they have no moving parts. Downtime is typically very short, and maintenance and repair can be done easily. Replacement parts are usually off-shelf. Cyclones have a long history of successful operation in a wide variety of applications; their functional life is usually more than 20 years.

Cyclones do not consume energy directly. The increased energy consumption attributable to cyclone operation is caused by the increased amount of fan power required to move flyash-laden flue gases through the unit. Flyash reinjection systems rarely exceed 5 hp.

Erosion from abrasive particles is sometimes encountered and may be reduced by keeping the particulate impingement angle at less than 20 degrees and by maintaining gas velocities below about 1500 fpm. Corrosion may be minimized by keeping flue gas temperatures above the dew point, insulating the cyclone, and using resistant alloys.

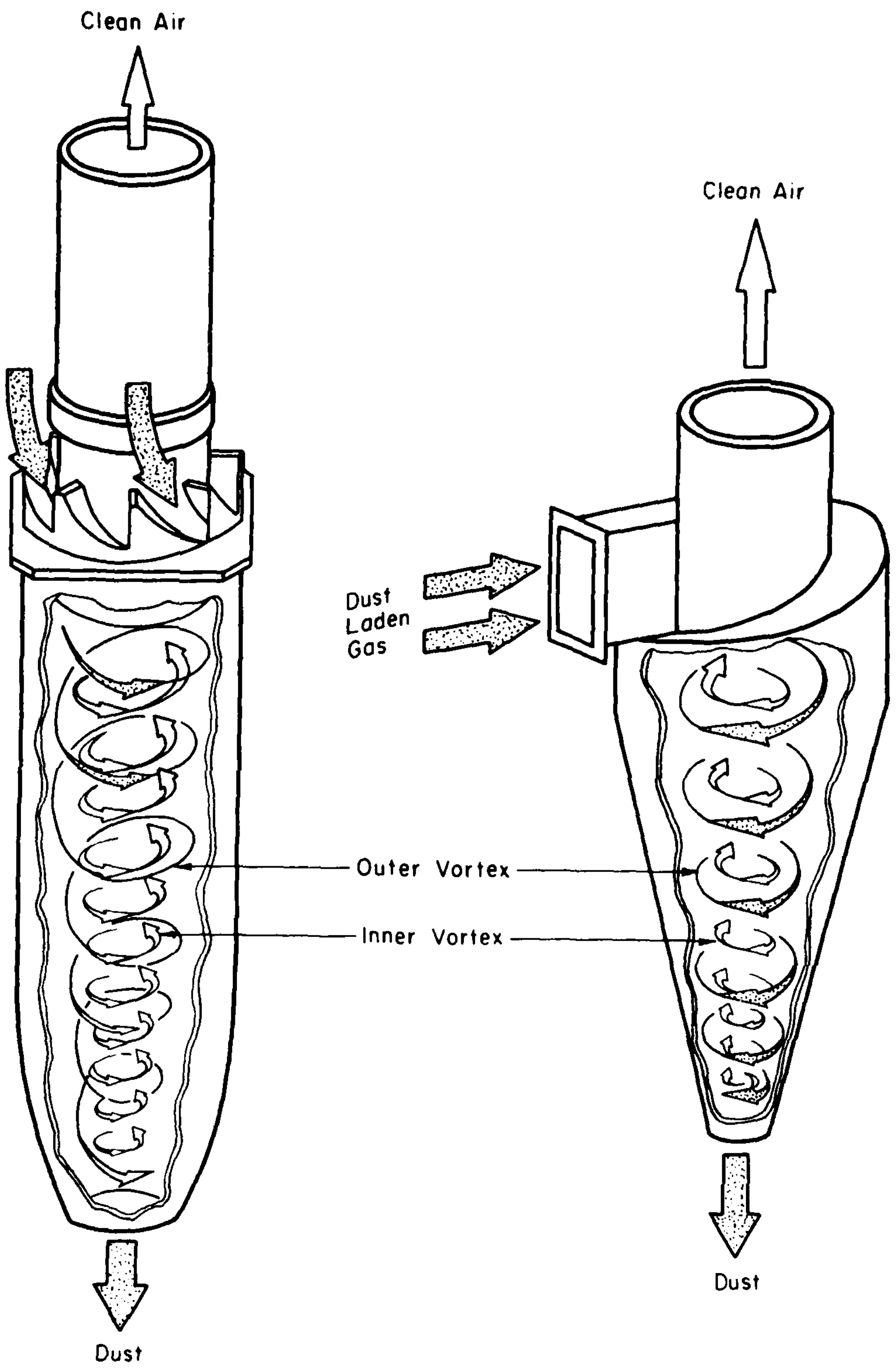


Figure 10. Cyclone operating principles. (From *Air Pollution Control Systems for Boiler and Incinerators* [U.S. Departments of Army, Navy, and Air Force, 1980].)

Particle buildup can be reduced by installing vibrators on the outside wall of the cyclone. Airtight construction and judicious selection and placement of fans will also help ensure good performance.

Cyclones are low in bulk and weight in comparison to other types of air pollution control equipment. Therefore, their retrofit problems are often minor. Their installation within the plant is determined by the amount of clearance between the combustor cold end and the stack. Cyclones are easily installed outdoors in limited-space situations, and have a low enough static load that rooftop location is usually not a problem.

Baghouses

A baghouse is a dry, mechanical-separation device that uses fabric filters to remove entrained particulates from the flue gas. These filters are made of woven or felted material shaped like a long tube. The filters are placed in a housing that has inlet and outlet connections, a dust storage hopper, and a filter cleaning mechanism.

Fabric filtration can be applied in any situation requiring high-efficiency particulate removal and meeting the following operating conditions:

1. Maximum operating temperatures between 450 and 550^{o}F (232 to 288^{o}C)

2. Minimal amount of resinous materials in the flue gas that are semisolid at the design operating temperature

3. Average operating temperatures that exceed the maximum dew points of any acids or alkalies produced by the controlled process

4. Minimal amounts of large, coarse, abrasive particulates

5. Minimal amounts of hygroscopic materials and/or moisture in the flue gas.

In actual use, the flue gas can be pretreated to minimize temperature and particulate grating effects. The other effects can be minimized by properly selecting fabric materials and operating conditions. Under optimum operating conditions, fabric filtration will remove 99 percent of the particulates that are larger than 0.5 microns at dust loadings up to 10 grains/cu ft (23 gr/m^3). Fabric filters have been used successfully in many industrial processes for byproduct recovery, as well as for solid-fuel-fired boilers and incinerators.

A baghouse has six basic parts: housing, inlet pipe, dust hopper, filter bags, cleaning mechanism, and outlet pipe (see Figure 11). In the basic baghouse operation, particle-laden flue gas enters the "dirty" gas side of the filter cells. From here, the flue gas migrates across the filter fabric to the "clean" gas side of the cell. In the process, entrained particulates are removed by a variety of mechanisms: direct interception, impingement, diffusion, and electrostatic attraction. Once the pressure drop on the filter exceeds a predefined value, loading of the filter cell ends and the cleaning cycle begins. Baghouses have three basic types of housing designs: open pressure, closed pressure, and closed suction (see Figure 12). Pressure system fans are on the "dirty" gas side of the system, while suction system fans are on the "clean" gas side. Open systems are usually cheaper to use than closed systems; suction systems have lower operations and

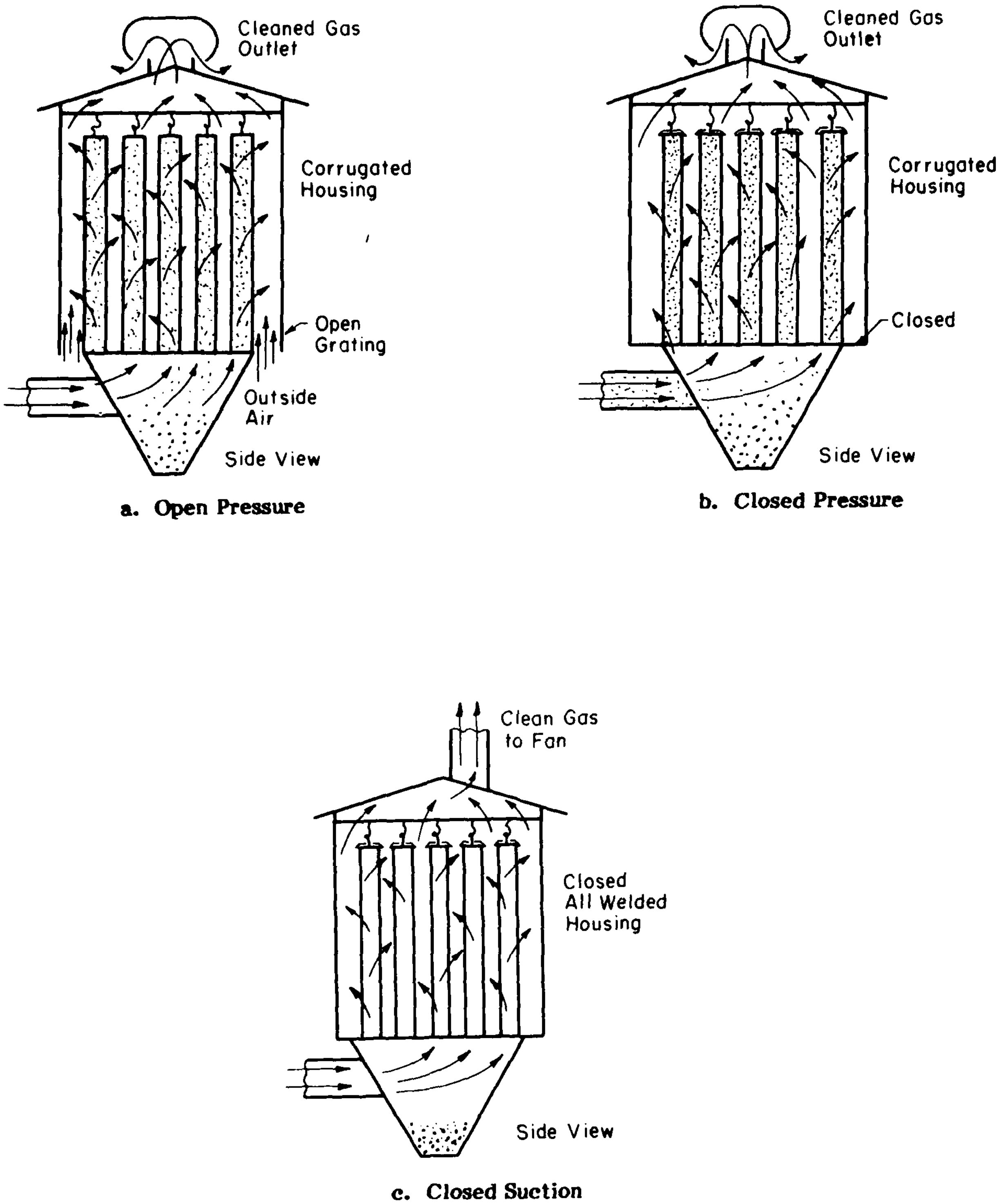


Figure 11. Typical baghouse (shake cleaning). (From *Air Pollution Control Systems for Boilers and Incinerators* [U.S. Departments of Army, Navy, and Air Force, 1980].)

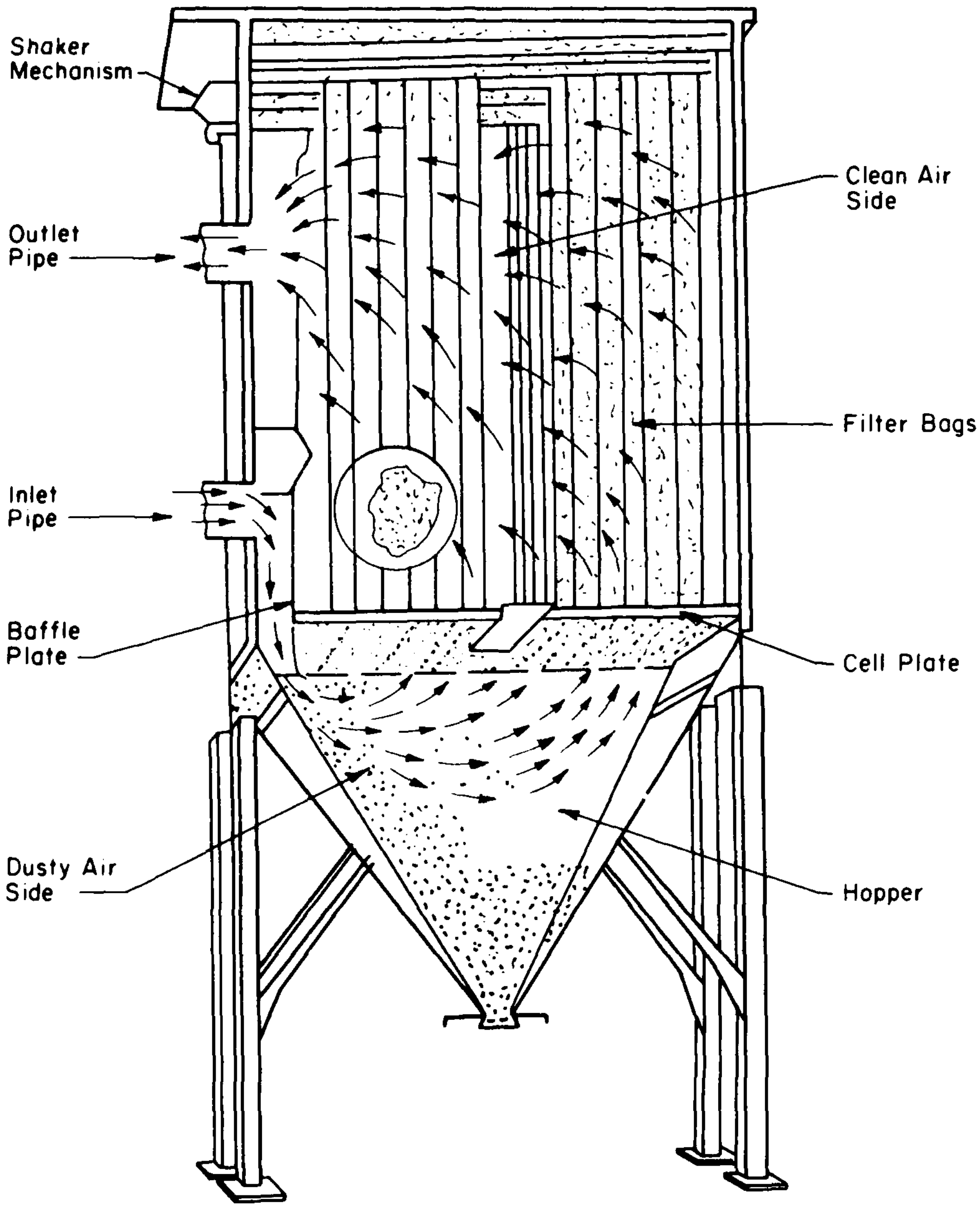


Figure 12. Baghouse construction. (From *Air Pollution Control Systems for Boilers and Incinerators* [U.S. Departments of Army, Navy, and Air Force, 1980].)

maintenance costs, but have higher capital costs than pressure systems. Cylindrical filters have upward or downward flow and inside or outside filtering (see Figure 13). The following operating characteristics apply for each of these systems:

1. Upward flow decreases fabric abrasion; only one manifold is required; extended time is allowed between bag cleanings

2. Downward flow gives better filtering performance, but bag tension is more difficult

3. Inside filtering permits bag inspection during operation

4. Outside filtering gives better filtering performance and provides increased fabric life, but also requires a supporting mesh.

Baghouses use four basic cleaning mechanisms: shaker, reverse flow, pulse jet, and reverse jet. Mechanical shaker systems are used for dusts with good cleaning properties (i.e., not sticky or abrasive). They require a low initial investment, but bag failure increases with the intensity and duration of shaking. Reverse-flow systems are used with a dust having good cleaning properties in high-temperature fiberglass bag systems. They have low fabric attrition; but require extra cloth and mechanical equipment. Pulse jet systems are very efficient for coal and oil flyash removal. The advantages of these systems are continuous cleaning and low fabric attrition; however, they require compressed air. Reverse jet systems are used to collect fine dusts and fumes. They control both cleaning intensity and frequency, but require compressed air and a great deal of mechanical equipment. Baghouses are usually built in separate modules for ease of cleaning and bag replacement. This type of system can be used in extensive turndown situations or during plant expansions.

The baghouse has the advantages of continuous high-collection efficiency under a variety of inlet loadings (concentration and sizing), insensitivity to ash chemistry and fuel sulfate content, insensitivity to particle size distribution, wide variety of size and flow configurations, ability to be used for flammable dusts, relatively easy maintenance, and provision of dry collected material. The baghouse's disadvantages are shortened bag life because of caustic atmospheres or elevated temperatures, maximum operating temperature limitation of 550°F, sensitivity to hygroscopic materials or moisture condensation which can lead to fabric plugging, high cost for special media, relatively short bag life (average 1.5 years, range 4 months to 5 years), retrofit problems created by bulky baghouse size, and extensive "dirty" side fan replacement caused by pressure flow systems.

A properly designed, sized, and operated baghouse can achieve a 99 percent (by weight) removal efficiency for particulates larger than 1 micron. This efficiency is relatively unaffected by boiler operating levels, fuel sulfur content, or the fuel's ash chemistry. When the baghouse is preceded by a mechanical collector, removal efficiencies can reach 99.8 percent (by weight).

Baghouses are generally very reliable if an applicable design and proper operating conditions are maintained. Most site-related operational problems occur during the first 2 years of operation. Modular construction isolates the outages to affected compartments, rather than taking the whole system off-line. Plant personnel can replace bags in a relatively short time (1/2 to 1 manhour/bag). Replacement parts are generally "off-the-shelf" items that are readily obtainable. Baghouses have an average operational life of 20 years (5- to 40-year range).

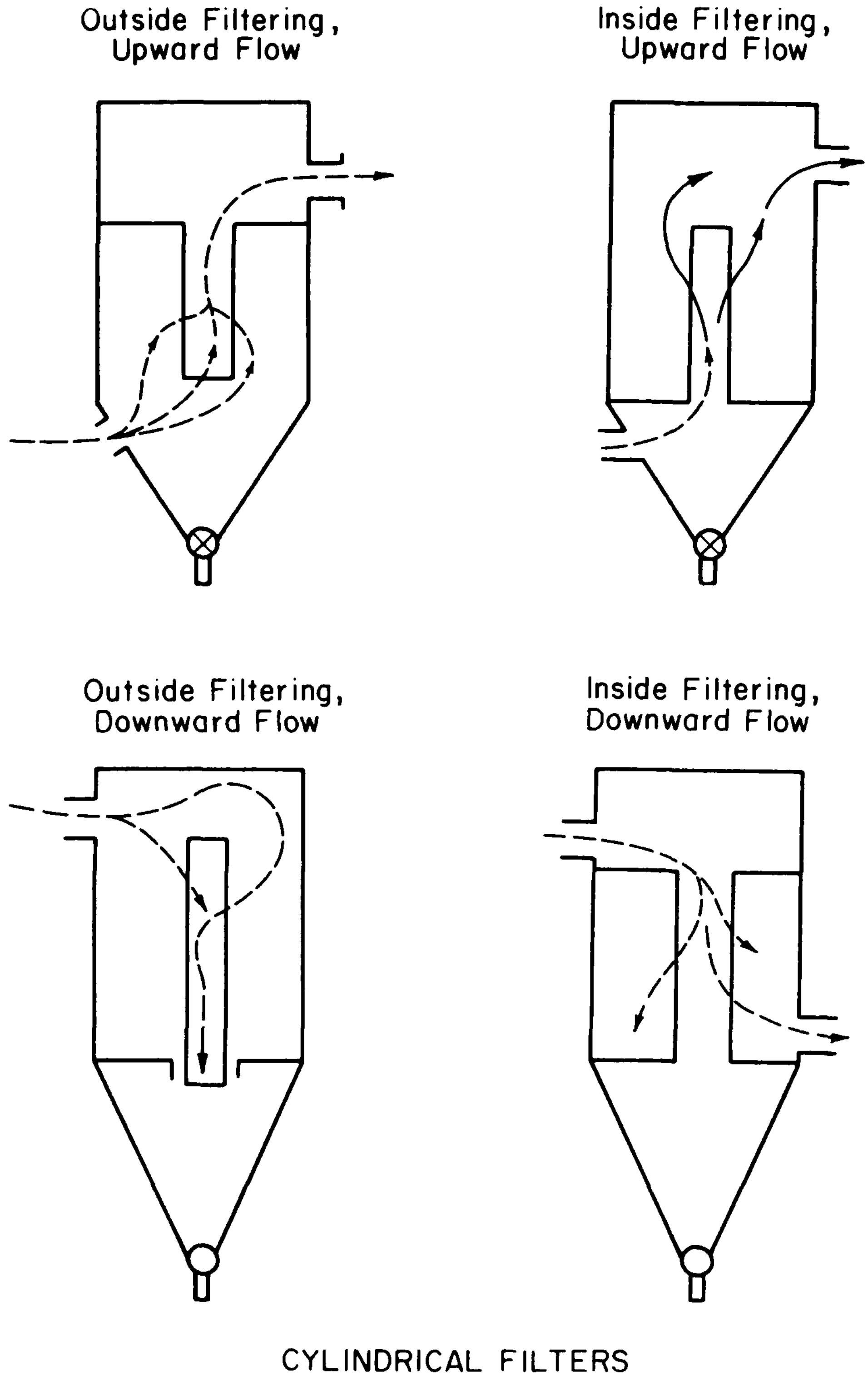


Figure 13. Airflow and filtering options.

Baghouses have a successful history of industrial byproduct removal, but their application to boilers and incinerators has been sporadic over the past 10 years; however, they are being used more as knowledge about the relative importance of their design parameters increases.

Most of the energy consumed in baghouse use is expended when the dust-laden gas is moved through the fabric filters. The pressure drop across the filter can range from 0.5 to 6 in. of water. The other major energy-using processes are the cleaning and dust disposal mechanisms, but the amount used is negligible in small to moderately sized units.

The factors that influence the performance of fabric filters can be grouped into two categories: design and operation. The design factors include type of fabric, method of cleaning, air-to-cloth ratio, design temperature, and design humidity. The operating factors include cleaning cycle frequency and duration, cleaning intensity, operating temperature, and operating humidity. The operating variables are adjusted to keep the system at design peak efficiency. Improper operation of the system will always give improper results, regardless of design. The most common operational problems are:

1. Filter clogging resulting from improper humidity and/or temperature conditions, or inefficient cleaning

2. Shortened bag life resulting from excessive temperature, acid/alkali condensation on the fabric, abrasive "grit" accumulation on the fabric, and excessive fabric cleaning

3. Corrosion of the "dirty" gas side surfaces resulting from improper surface coating or from excessive concentrations of corrosives and/or abrasives in the "dirty" gas.

The major retrofit consideration is the bulky size of the baghouses; because of their size, most baghouses are located outside the plant, although the low static load of baghouse units sometimes allows them to be placed on the plant roof. External location usually requires extra air-moving equipment, ducting, and insulation in addition to expenditures for the basic baghouse equipment. An advantage of the baghouse system is that it can be compartmentalized to handle several boilers at one location.

Electrostatic Precipitators

An electrostatic precipitator (ESP) (Figure 14) is a device that removes solid or liquid particles from a gas stream by means of an electrically charged field. This electric field imparts a positive or negative charge to the particles, so that they are attracted to an oppositely charged collection surface. Collected particles are removed from the collection plate by rapping or vibration.

Electrostatic precipitators can be used in any application where the contaminant particulates will accept and hold an electrical charge. Originally, precipitators were used to remove sulfuric acid mists from explosive and acid-manufacturing plants. Later applications included particulate removal from lead blast furnaces, smelting furnaces, ore roasters, cement kilns, pulp dryers, and paper recovery boilers. Currently, the largest application of ESP is for flyash collection from coal-fired power plants.

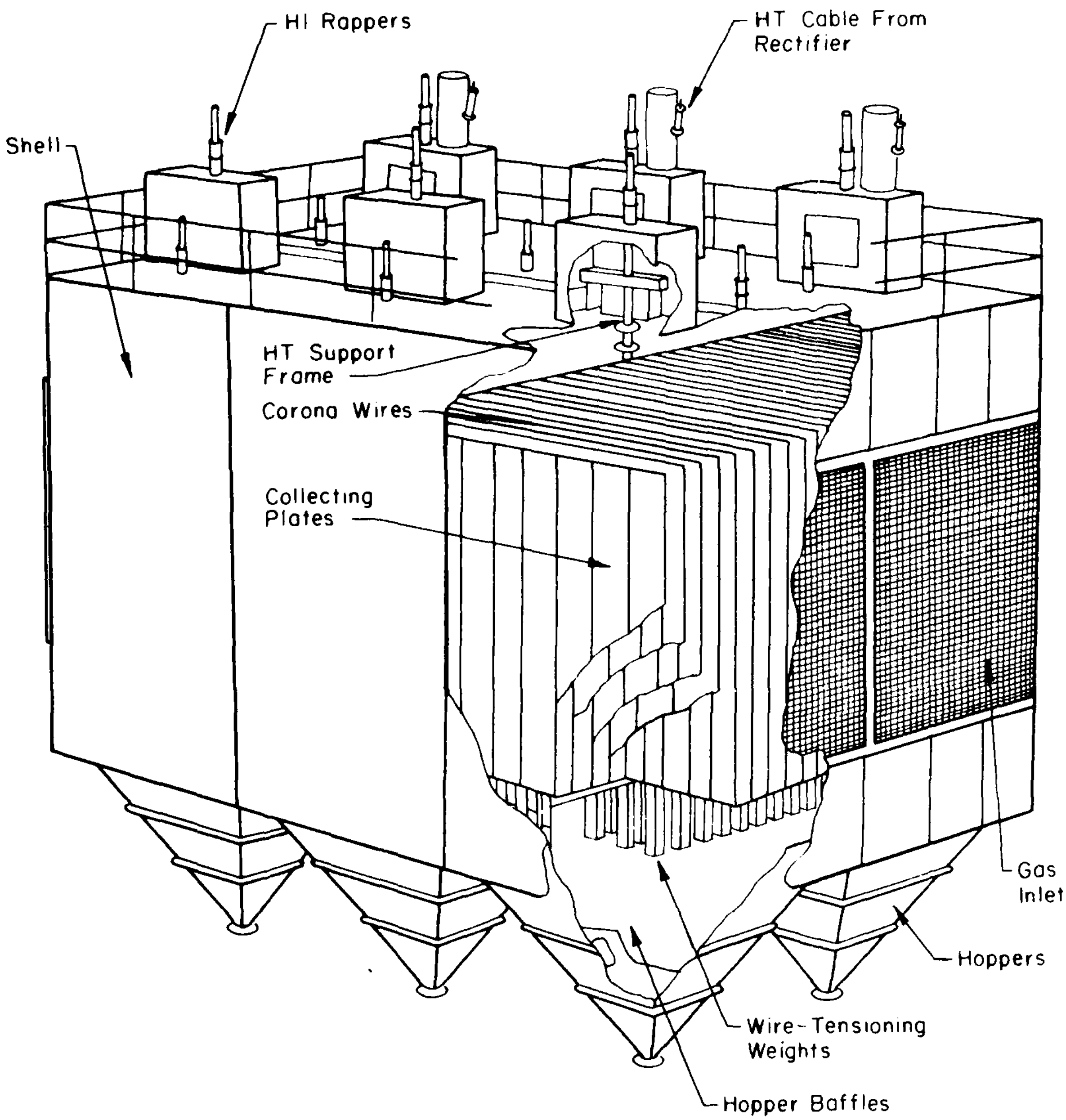


Figure 14. Basic structure of a typical precipitator. (Western Precipitation, Division of Joy Manufacturing Company, Los Angeles, CA). (From *Control Techniques for Particulate Emissions From Stationary Sources - Volume 1*, EPA-450/3-81-005a [USEPA, Office of Air Quality Planning and Standards, September 1982].)

Parallel plate precipitators are the most commonly used ESPs for boiler applications. Retrofit applications will usually use the "cold" type precipitator (below 300^{o}F), while new applications predominantly use the "hot" type precipitator (above 600^{o}F).

Europeans have successfully used electrostatic precipitators on incinerators for many years. However, the United States has only recently begun using precipitators for high-efficiency particulate removal on large incinerators.

In electrostatic precipitation, an active electrode imparts a charge to the entering particulates, and a passive electrode acts as a collecting surface for the charged particulates. A high direct current voltage (20 kV/cm) is placed on the charging electrode, which creates a corona of gaseous ions. These ions are accelerated to high velocities and collide with the particulates flowing through the field. This collision ionizes the particulates, which then migrate to the oppositely charged collector electrode. The particle charge is neutralized at the collector electrode, and the particulates are removed by vibration, mechanical rapping, or water spray.

There are two basic types of precipitators: two-stage and single-stage. Two-stage ESPs, which have the charging electrode located upstream from the collection plates, are used for localized particulate collection (paint spray booths, tool grinding areas, etc.) and are commercially available in sizes up to 20,000 cu ft/min.

The single-stage ESP is the most commonly used. The construction of this type of precipitator can be either tube-type or parallel plate (see Figure 15). Tube-type ESPs, usually used for small gas volumes, consist of a single-wire charging electrode running down the center of a tube-shaped collector electrode. Plate-type ESPs suspend vertical wire-charging electrodes between the parallel collection plates.

ESPs can be operated in either a "hot" or "cold" precipitation mode. A "hot" system is located on the boiler side of the air preheater and operates at temperatures in excess of 600^{o}F. It has the advantage of decreasing particle resistance to collection and therefore improving collected particle removal; its disadvantage is that it requires more collector surface because of the lower particle charge. Because hot ESPs require extra ductwork to return the treated flue gas to the air preheater and extra space to accommodate large collection surfaces, they are usually used in new construction where they can be built in economically.

"Cold" ESPs operate at below 300^{o}F and are located on the stack side of the preheater. They have the advantage of smaller collector surfaces and smaller air-handling equipment requirements, however, they tend to have acid mist corrosion problems. Cold ESPs are generally used in retrofit situations.

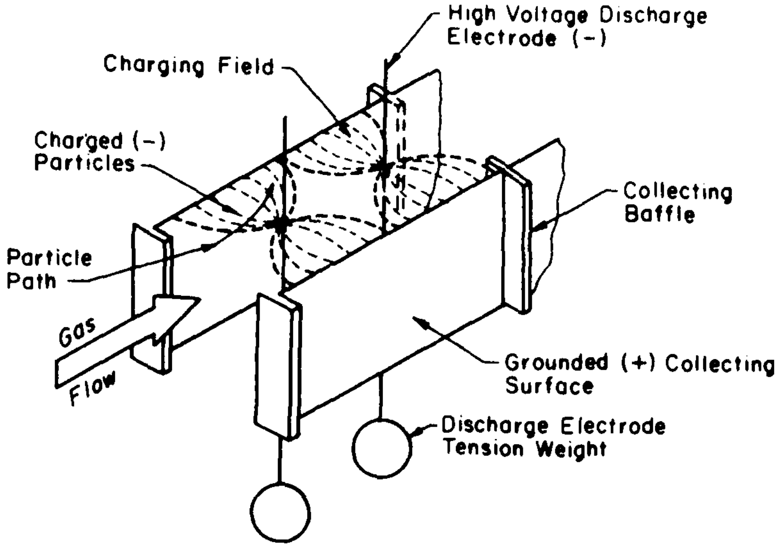
The advantages of ESPs are:

1. High particle collection efficiency (up to 99 percent by weight)

2. Efficient collection of particles down to 2 microns, with lower limits down to 0.1 micron

3. Dry collection of particles for possible byproduct recovery

4. Small pressure and temperature drops



Schematic View of a Flat Surface-Type Electrostatic Precipitator

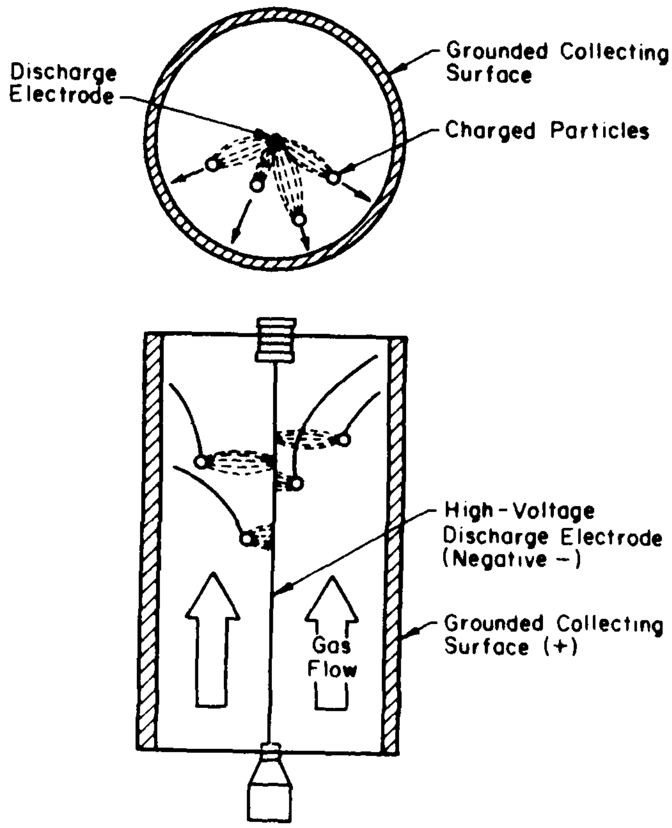


Figure 15. Alternate electrode configurations. (From *Air Pollution Control Systems for Boilers and Incinerators* [U.S. Departments of Army, Navy, and Air Force, 1980].)

5. Low maintenance requirements and very few moving parts

6. High temperature tolerances (up to $1000^{o}F$)

7. Effective collection of acid mists, tar mists, and aerosols

8. Capability of handling very large flow rates.

The disadvantages of ESPs are:

1. High initial capital cost

2. Very bad turndown capability; ESPs are most successful under constant design conditions

3. Inability to collect certain materials because they cannot hold a substantial charge

4. Large space requirements

5. Inability to operate well under surge loading

6. Collection efficiency decreases as dust loading increases, often requiring cyclone pretreatment of the flue gas to achieve high efficiency

7. System breakdowns tend to stop the whole ESP operation

8. High voltage requires special safeguards to protect service personnel

9. Higher collection efficiencies greatly increase the capital investment (80 to 96 percent doubles the cost; 80 to 99 percent triples the cost)

For a properly designed system operating at constant design conditions and having a steady dust load, particle removal efficiencies can exceed 99 percent (by weight). The ESP will collect particles ranging from 0.1 to 200 microns in size and particle concentrations ranging from 0.0001 to 100 grains/cu ft (0.0002 to 229 gr/m^3). Systems can be designed to handle from 1 to 3,000,000 cu ft/min. Collection efficiencies are greatly affected by variations in operating conditions, particle loadings, and flue gas volumes.

Properly designed ESPs operated under constant conditions are very reliable, mainly because they have no moving parts, and therefore require very little maintenance. However, when ESPs do break down, the total particulate collection system must be shut down for repair. This condition occurs if one of the main components breaks or if the system must be shut down for repair work. The operating life of an ESP ranges from 5 to 40 years, with an average of 20 years.

Commercial ESPs have been used since 1907 and were first applied to coal-fired boilers in 1923. ESPs have an extensive operating history in the ferrous and nonferrous metal industry, paper mills, acid production industry, cement kilns, and oil refineries, and in flyash collection from power plants.

Because of the low pressure drop (1/2 to 1 in. water gage) through the system, air-handling systems are relatively small. The majority of power is consumed by the corona

generation and cleaning mechanisms. Positive-corona ESPs consume slightly more power in the cleaning cycle than negative-corona ESPs.

In a properly designed ESP, the factors affecting collection efficiency and system performance stem from either variations in the collected particles or in system operation conditions. Variability in the particle properties of the charge acceptance, particle size distribution, condensation dew points, moisture content, ash content, and sulfur content can greatly change collection efficiency and the amount of system maintenance required, as will variations in the operating parameters of temperature, gas flow rate, gas flow uniformity, inlet particle loading, collection plate cleaning, power supply, and storage hopper cleaning.

The first major consideration in using ESPs for boilers or incinerators is the ability to maintain collected particle properties within design specifications (i.e., consistent in size and resistivity). If there will be great variety in the ash content, sulfur content, size distribution, and particle resistivity of the collected particles, ESPs will not perform satisfactorily. The second consideration is the ability to maintain operating conditions within design specifications. These conditions include operating temperature, gas flow rate, gas flow uniformity, and inlet dust loading.

For retrofit applications, several other factors must be considered. First, the bulky size of ESP units creates problems in locating them in the plant. Usually, they will be located outside, which requires extra ductwork for gas transport and extra insulation for operating temperature maintenance. Second, ESP units use very high voltages, so special safety precautions must be provided for maintenance personnel. Also, ESP units do not have a good "turndown" capability. If a "turndown" capacity is required, the ESP must be built in separate, independent sections, interconnected by a series of manifolds. Sectional ESPs have a history of higher maintenance requirements.

6 SUMMARY

This report has outlined the principal processes involved in heat-recovery incineration, applicable air pollution regulations, expected emissions, and potential air pollution control technologies. The following specific observations were made from the information obtained:

1. Modular heat-recovery incinerators that burn municipal-type waste, have 50 TPD or less waste input, and function primarily to reduce solid waste are regulated by state regulatory agencies.

2. Small modular incinerators that burn municipal waste are only regulated for particulate emissions and visibility of the plume.

3. The most common state regulation for municipal incinerators with heat recovery is 0.10 gr/dscf corrected to 12 percent CO_2 and 20 percent opacity (No. 1 on the Ringelmann scale).

4. Units greater than 50 TPD must meet the USEPA NSPS regulation for particulates of 0.08 gr/dscf corrected to 12 percent CO_2.

5. Because heat-recovery incinerators are classified as both an incinerator and a boiler, the state air pollution source permit application must contain information on both systems.

6. Pollutants that may be regulated in the future are chlorides and fine particulates (less than 10 microns).

7. Emissions from small modular incinerators have been documented primarily for particulates. There has been recent research on other emissions such as chlorides, heavy metals, and fine particulates.

8. Starved-air HRIs have been shown to be capable of meeting TSP regulations with or without extensive air pollution control devices.

9. Cyclones, baghouses, and electrostatic precipitation are the three major technologies for controlling the primary pollutant from incinerators.

METRIC CONVERSION FACTORS

1 lb	=	0.4535 kg
1 ton	=	0.907 tonne
1 Btu	=	1.055 kJ
1 cu ft	=	0.0283 m^3
1 in.	=	25.4 mm
^{o}C	=	(^{o}F-32) (5/9)

REFERENCES

Air Pollution Control Systems for Boilers and Incinerators (U.S. Departments of the Army, Navy, and Air Force, 1980).

A. M. Kinney, Inc., *Emerging Technology for the Control of Emissions from Existing Army Boilers and Incinerators*, Technical Report N-19/ADA037494 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1977).

Beak Consultants Inc., *Report of Particulate Matter Emission Test on Kelley Model 1280/72 Installed at Freightliner Corporation, Portland, Oregon* (Freightliner Corporation, 1979).

Beling Engineering Consultants, *Report on Basic Incinerator Emission Test for Basic Engineering, Inc.* (Basic Engineering, Inc., 1972).

Brickner, Robert H., and Brenda Harrison, "Small May Be Better; Modular Combustion Offers an Alternative to Municipalities Without Large Volumes of Waste," *Waste Age* (March 1980), pp 28-36.

Cal Recovery Systems, Inc., *Survey of Small Heat-Recovery Incinerators* (U.S. Naval Civil Engineering Laboratory, 1983).

Chase, Malcolm J., and Thomas C. Pond, "Modular Combustion System Solves Regional Solid Waste Problem," *Public Works* (July 1981), p 2.

City of Orlando and Buckley Post, Schuh, and Jernigan, Inc., *City of Orlando: Resource-Recovery Project, Final Feasibility Study* (U.S. Department of Energy, 1982).

Compilation of Air Pollutant Emission Factors, third edition (including Supplements 1-12), Publication No. AP-42 (USEPA, Office of Air Quality Planning and Standards, 1977).

Cross, Frank L., Jr., and Howard E. Hesketh, eds., *Handbook for the Operation and Maintenance of Air Pollution Control Equipment* (Technomic Publishing Co., Inc., 1975).

DeMarco, Jack, Daniel J. Keller, Jerold Leckman, and James Newton, *Incinerator Guidelines* (U.S. Department of Health, Education, and Welfare, 1969).

Drinkwater, Alford, "Modular Incineration: An Energy Recovery Option for the Smaller City; Durability, Resale Potential Open Competitive Possibilities," *Solid Waste Management*, Vol 24, No. 5 (May 1981).

Erlandsson, Kjell I, *Report of Particulate Matter Emission Tests on Kelley Model 780 Pyrolytic Incinerator* (Kelley Company, Inc., 1976).

Frounfelker, R. E., and N. J. Kleinhenz. "A Technical Evaluation of Modular Incinerators with Heat Recovery," *Journal of Energy Resources Technology*, Vol 103 (December 1981), pp 265-269.

Gammie, Leigh, and TRC Environmental Consultants, Inc., *Report on Particulate Emissions from the Kelley Pyrolytic Incinerator at the State Veterans Home and Hospital in Rocky Hill, Connecticut* (Kelley Company, Inc., 1981).

Hathaway, S. A., and J. P. Woodyard, *Technical Evaluation Study: Solid Waste as a Fuel at Ft. Bragg, NC*, Technical Report E-95/ADA034416 (USA-CERL, 1976).

Helmstetter, Arthur J., "Basic Design, Economical, and Environmental Control Considerations for Waste-to-Energy Conversion Systems," *Plant Engineering*, Vol 35, No. 17 (August 20, 1981), pp 83-85.

Hoffman, Ross E., "Refuse-to-Energy in Less Than Two Years," *Public Works* (March 1983), p 3.

I. I. A. Incinerator Standards (Incinerator Institute of America, 1968).

Incinerator Emission Testing for Kelley Company Meredith, New Hampshire Municipal Waste Model 1280 (Kelley Company, Inc., 1977).

Informational Package on Trofe Incineration, Inc. (Trofe Incineration, Inc., 1982).

Jahnke, J. A., J. L. Cheney, and C. R. Fortune, "A Research Study of Gaseous Emissions from a Municipal Incinerator," *Journal of the Air Pollution Control Association*, Vol 27, No. 8 (August 1977), pp 747- 753.

J. E. Sirrine Company, *Particulate Stack Test Smokatrol Model No. 200 Greeneville, South Carolina Sirrine Job No. 7951* (Smokatrol, Inc., 1972).

Levy, Paul F., "Arkansas: Recovery Success Story," *Waste Age* (January 1981).

Lingua, M., and J. Zimmerle, *Preliminary Performance Criteria for Heat Recovery Incinerator Using Refuse as a Fuel* (U.S. Naval Civil Engineering Laboratory, 1982).

Martin, A. E. ed., *Small Scale Resource Recovery Systems* (Noyes Data Corporation, 1982).

"Modulars Made for the '80s," *Waste Age* (May 1980), pp 33-39.

National Loss Control Service Corporation, *Incinerator Emission Study for Kelley Company, Inc.: Alexian Brothers Medical Center, Elk Grove Village, Illinois* (Cook County Department of Environmental Control; Kelley Company, Inc., 1977).

Niessen, Walter R., and Thomas C. Pond, "Modular Combustion Units," *Public Works* (May 1980), p 3.

Particle Data Laboratories, Ltd., *Particulate and Carbon Monoxide Emission Testing on Basic Incinerator Located at Dominick's Melrose Park, IL* (Basic Engineering, 1976).

Particulate Emissions Tests Comtro Model A-50 Incinerator: Douglas Furniture Company (Sunbeam Equipment Corporation, 1978).

Particulate Emissions Test; Jacksonville Naval Air Station Waste Heat Recovery System: Comtro Model A-48 Incinerator (Sunbeam Equipment Corporation, 1979).

Particulate Emission Test on a Unit Processing Solid Waste (ThermAll, Inc., 1982).

Reilly, Thomas C., and Diana L. Powers, "Resource Recovery Systems; Part II: Environmental, Energy, and Economic Factors," *Solid Waste Management*, Vol 23, No. 6 (June 1980), pp 38-42.

Report of Particulate Matter Emission Tests on Kelley Model 780 Pyrolytic Incinerator When Burning Pathological Waste (Kelley Company, Inc., 1976).

Report of Source Emission Testing on Kelley Hoskinson Incinerator Model 1280; Milwaukee, Wisconsin (Kelley Company, Inc., 1973).

Ross Hoffman Associates, *Evaluation of Small Modular Incinerators in Municipal Plants*, EPA-530/SW-113c, NTIS PB-251291, (U.S. Environmental Protection Agency [USEPA], 1976).

Schanche, Gary W. and Bernard A. Donahue, *Air Pollution Survey Guidelines for Army Installations*,Technical Report N-5/ADA029633 (USA-CERL, 1976).

Schanche, Gary W., John R. Cannon, Larry R. Greep, and Bernard A. Donahue, *Pollution Estimation Factors*, Technical Report N-12/ADA033753 (USA-CERL, 1976).

Schanche, Gary W., Larry A. Greep, and Bernard A. Donahue, *Installation Solid Waste Survey Guidelines*, Technical Report E-75/ADA018879 (USA-CERL, 1975).

SCS Engineers, *Resource Recovery Technology Application Document* (U.S. Naval Civil Engineering Laboratory, 1982).

Source Category Survey: Industrial Incinerators, EPA-450/3-80-013 (USEPA, Emission Standards and Engineering Division, 1980).

Stationary Air Pollution Source Assessment No. 42-21-0348-83, Heat Recovery Incinerator Fort Eustis, VA (U.S. Army Environmental Hygiene Agency, 1982).

Stephen W. Upson, Associates, Inc., *Particulate Emissions Tests E.C.P. Incinerator/Heat Recovery System; Ft. Leonard Wood, MO* (Environmental Control Products, Inc., 1982).

Summary of Test Burn Results (Industronics, Inc., 1983).

Systech Corporation, *Test and Evaluation of the Heat Recovery Incinerator System at Naval Station, Mayport, Florida* (U.S. Naval Civil Engineering Laboratory, 1981).

"Table Gives Resource Recovery Update in Four Activity Categories," *Solid Waste Management*, Vol 23, No. 11 (November, 1980), pp 57-65.

Control Techniques for Particulate Emissions From Stationary Sources, Volume 1, EPA-450/3-81-005a (USEPA, Office of Air Quality Planning and Standards, September 1982).

Webster, R. D., et al., *Modification and Extension of the Environmental Technical Information System for the Air Force*, Technical Report N-81/ADA079441 (USA-CERL, 1979).

van Weringh, J., et al., *Computer-Aided Environmental Legislative Data System (CELDS) User Manual*, Technical Report N-56/ADA061126 (USA-CERL, 1978).

Woodyard, John P., and SCS Engineers, Inc., "Energy Recovery From Solid Waste Using Modular Incinerators: A Report of the U.S. Experience," *The Journal of Environmental Sciences*, Vol 24, No. 5 (September/October 1981), pp 27-32.

LIST OF ACRONYMS

ASME - American Society of Mechanical Engineers

ASTM - American Society for Testing and Materials

CELDS - Computer-Aided Environmental Legislative Data System

CFR - Code of Federal Regulations

DA - Department of the Army

ECIP - Energy Conservation Investment Program

ESP - electrostatic precipitator

ETIS - Environmental Technical Information System

ETP - Emissions Trading Procedures

HRI - heat-recovery incinerator

HRIFEAS - Heat Recovery Incinerator Feasibility

IIA - Incinerator Institute of America

NAAQS - National Ambient Air Quality Standards

NESHAPS - National Emission Standards for Hazardous Air Pollutants

NSPS - New Source Performance Standard

PSD - Prevention of Significant Deterioration

PVC - polyvinyl chloride

SIP - State Implementation Program

TPD - tons per day

USA-CERL - U.S. Army Construction Engineering Research Laboratory

USEPA - U.S. Environmental Protection Agency

APPENDIX A:

EXAMPLE AIR POLLUTION PERMIT APPLICATION

PERMIT APPLICATION

TO CONSTRUCT OR OPERATE AN AIR CONTAMINANT SOURCE

DEP-7007

FORMERLY APC-110

COMMONWEALTH OF KENTUCKY
CABINET FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
DEPARTMENT FOR ENVIRONMENTAL PROTECTION
DIVISION OF AIR POLLUTION CONTROL
FORT BOONE PLAZA
18 REILLY ROAD
FRANKFORT, KENTUCKY 40601

Commonwealth of Kentucky
Natural Resources & Environmental Protection Cabinet
Department for Environmental Protection
Division of Air Pollution Control
Ft. Boone Plaza, 18 Reilly Road
Frankfort, Kentucky 40601

DEP7007 Administrative Information
AGENCY USE ONLY
ID No:
DATE RECEIVED:
LOG No:

PERMIT APPLICATION TO CONSTRUCT OR OPERATE AN AIR CONTAMINANT SOURCE

The completion and return of this form is required under Regulation No. 401 KAR 50:035, pursuant to KRS 224. Applications are incomplete unless accompanied by copies of all plans, specifications and drawings requested herein. Failure to supply information required or deemed necessary by the Division to enable it to act upon the application shall result in administrative or legal action.

1. OFFICIAL COMPANY NAME *(ALSO ENTER PLANT OR DIVISION NAME, IF ANY)*:

2. MAILING ADDRESS:

   Street or Box No. *City* *County* *State* *Zip Code*

3. ACTUAL PLANT LOCATION:

   Street *City* *County* *State* *Zip Code*

4. ADDITIONAL PLANT LOCATION INFORMATION *(IF KNOWN)*:

   LATITUDE: ____ *Degrees* ____ *Minutes* ____ *Seconds* UTM COORDINATES: *Horizontal* *Km*

   (OR)

   LONGITUDE: ____ *Degrees* ____ *Minutes* ____ *Seconds* ZONE: *Vertical* *Km*

5. PROPERTY AREA AND NUMBER OF EMPLOYEES AT ABOVE LOCATION:

   AREA: ____________ *acres or* ____________ *sq.ft.* NUMBER OF EMPLOYEES: ____________

6. NAME AND TITLE OF PERSON TO CONTACT ON AIR POLLUTION MATTERS:

   NAME: TITLE:

7. TELEPHONE NUMBER *(WITH AREA CODE)* AND MAILING ADDRESS OF CONTACT PERSON:

8. GENERAL NATURE OF BUSINESS *(E.G., PRINCIPLE PRODUCTS, SERVICES, ETC.)* AND STANDARD INDUSTRIAL CLASSIFICATION CODE(S):

   NATURE: CODE(S):

DEP-7007
(Rev. 11/82)

DEP 7007
Continued

9. TOTAL COST OF PLANT: $ ____________ *(Including property, buildings and air pollution control equipment)* COST OF PROPOSED CONSTRUCTION *(Construction Applications Only)*: $ ________	10. AMOUNT OF FILING FEE ENCLOSED $ ________

11. PURSUANT TO THE PROVISIONS OF KENTUCKY AIR POLLUTION CONTROL REGULATION NO. 401 KAR 50:035, APPLICATION IS HEREBY MADE FOR *(Check only one)*:

- ☐ A permit to construct an air contaminant source *(e.g. construct, install, reconstruct, modify, replace or alter)*
- ☐ A permit to operate an air contaminant source

12. PRESENT STATUS OF EQUIPMENT *(Check appropriate box(es) and complete applicable items)*

OPERATING PERMIT:

- ☐ For existing plant, date construction completed ____________
- ☐ Name change pending, effective date ____________

CONSTRUCTION PERMIT:

	Estimated Starting Date	Estimated Completion Date
☐ Equipment to be modified or constructed		
O Basic Equipment	________	________
O Air Pollution Control Equipment	________	________
☐ Change of location pending	________	________

13. INDICATE THE TYPE(S) AND NUMBERS OF FORMS ATTACHED AS PART OF THIS APPLICATION:

	DEP			DEP	
____	7007A	Indirect Heat Exchanger	____	7007K	Surface Coating or Printing Operations
____	7007B	Manufacturing or Processing Operations	____	7007L	Concrete, Asphalt, Aggregate, Coal, Other
____	7007C	Incinerators and/or Waste Burners	____	7007M	Metal Cleaning Degreasers
____	7007E	Monitoring Equipment	____	7007N	Air Pollution Control Equipment
____	7007F	Episode Standby Plan	____	7007P	Perchloroethylene Dry Cleaning Systems
____	7007G	Compliance Schedule	____	7007R	Emission Reduction Credit (ERC)
____	7007J	Petroleum Storage	____	7007S	Service Stations

14. CHECK OTHER ATTACHMENTS WHICH ARE PART OF THIS APPLICATION:

Required Data:	Supplemental Data:
☐ Plant Location Map	☐ Calculation Sheets
☐ Process Flow Diagram	☐ Stack Test Reports
	☐ Other (Specify)

15. CHECK ALL HAZARDOUS MATERIALS OR COMPOUNDS OF SUCH MATERIALS EMITTED INTO THE ATMOSPHERE FROM ANY OPERATION OR PROCESS AT THIS LOCATION:

☐ Antimony	☐ Tin	☐ Bismuth	☐ Bromide	☐ Silica
☐ Beryllium	☐ Chloride	☐ Mercury	☐ Asbestos	☐ Vinyl Chloride
☐ Lead	☐ Arsenic	☐ Fluorides	☐ Cadmium	

☐ Other Hazardous Material(s) as specified in 40 CFR Part 260, Appendix VIII:

☐ None

16. NAME OF PERSON SUBMITTING APPLICATION (Type or Print)	TITLE	PHONE NUMBER

17. **IMPORTANT: APPLICATIONS WILL BE RETURNED IF THEY ARE NOT SIGNED.** Applications shall be signed by the corporate president, his authorized agent, plant owner or operator, highest elected official, or equivalent.

SIGNATURE OF PERSON SUBMITTING APPLICATION — DATE OF APPLICATION

DEP7007A

INDIRECT HEAT EXCHANGER

[Make copies of this form if you have more than one unit. One completed form **DEP7007A** *shall be submitted for each individual unit.]*

1. Type of Unit *(Make, Model, Etc.)*: ____________________

____

Date Installed: ____________ Cost of this unit: $ ____________

Where more than one unit is present, identify with Company's identification or code for this unit:

____

____

2. Rated Capacity - Input (BTU/Hr.): ____________________
(Refer to manufacturer's specifications, if necessary.)

3. Does this unit belong to one of the following categories *(Check)*?

☐ YES

☐ NO

◯ A. Indirect heat exchangers used solely for heating residential buildings not exceeding a total of six apartment units;

◯ B. Any installations with a capacity of less than 1 million BTU per hour input;

◯ C. Any installations using natural or liquified petroleum gas, including those having distillate fuel oil as standby fuel with a capacity of less than 50 million BTU per hour input;

◯ D. Marine installations and locomotives;

◯ E. Internal combustion engines and vehicles used for transportation of passengers or freight.

If the answer is YES, you are required to complete SECTION I ONLY.

If the answer is NO, complete both SECTIONS I and II.

SECTION I. FUEL

4. Type of Primary Fuel *(Circle)*:

A. Coal

B. Fuel Oil # *(Check one)*

1	2	3	4	5	6

C. Natural Gas D. Propane E. Butane F. Wood

G. Other *(specify)*: ____________________

____

5. Secondary Fuel *(if any, specify type)*: ____________________

Page ______ of ______

APC 110A (8/80)

6. Fuel Composition:

Type	Percent Ash[a]			Percent Sulfur[b]			BTU/Unit Quantity[c,d]		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Primary									
Secondary									

7. Fuel Usage:

MONTH	RESPECTIVE QUANTITIES[d]		MONTH	RESPECTIVE QUANTITIES[d]	
	PRIMARY	SECONDARY		PRIMARY	SECONDARY
January			July		
February			August		
March			September		
April			October		
May			November		
June			December		
			Yearly Total		

a. As received basis, Proximate Analysis for Ash.
b. As received basis, Ultimate Analysis for Sulfur.
c. Higher heating value, BTU/unit.
d. Suggested units are: tons for solid fuels, 1000 gallons for liquid fuels and 1000 cu.ft. for gaseous fuels. If other units are used, please specify.

____

8. Fuel source or supplier: ______________________________

____

9. Normal operating schedule for this unit:

________ hours/day ________ days/week ________ weeks/year

10. If this unit is multipurpose, describe percent in each use category:

Space Heat ________ %; Process Heat ________ %; Power ________ %

11. IMPORTANT. Complete **DEP7007N** for Air Pollution Control Equipment and stack parameters. If there is no control equipment, complete only Section I of **DEP7007N**.

DEP 7007A Continued

SECTION II — Complete Section II, only if you answered NO to item 3

12. Coal-Fired Unit

Fly Ash Reinjection: ○ yes ○ no

☐ Pulverized

○ Dry Bottom

○ Wet Bottom

☐ Stoker-fired

○ Spreader Stoker

○ Other Stoker

☐ Cyclone ☐ Hand-fired ☐ Other *(specify)* ______

13. Oil-Fired Unit

☐ Tangentially-fired ☐ Horizontally-fired

14. Wood-Fired Unit

Fly Ash Reinjection: ○ yes ○ no

☐ Pile ☐ Thin bed ☐ Cyclonic

15. Combustion air: Draft: ○ Natural ○ Induced

Forced pressure ______ lbs./sq. in.

Percent excess air *(air supplied in excess of theoretical air)* ______ %.

16. Additional Stack Data:

A. Number of sampling ports provided ______.

B. Nearest distance from sampling port downstream to stack outlet, or first bend or obstruction ______ ft.

C. Nearest distance from sampling port upstream to last bend or obstruction ______ ft.

D. List other sources vented to this stack ______

______

17. Attach manufacturer's specifications and guaranteed performance data for the indirect heat exchanger and air pollution control equipment. Include information concerning fuel input, burners and combustion chamber dimensions.

18. Describe fuel transport, storage methods and related dust control measures; including ash disposal and control.

______

______

______

Kentucky Department for Natural Resources & Environmental Protection
DIVISION OF AIR POLLUTION CONTROL

PERMIT APPLICATION

DEP7007C
INCINERATORS AND/OR WASTE BURNERS

POINT OF EMISSION NUMBER: ______________

This section must be completed for any apparatus used to ignite and burn solid, liquid or gaseous combustible wastes. Items 1, 2, 3, and 4 are design criteria on the incinerator manufacturer's name plate. The name plate should be in a conspicuous place on the incinerator.

1. MANUFACTURER'S NAME:

2. MODEL NUMBER:

3. RATED CAPACITY:

______________ lb. per hour, or ______________ tons per hour

4. TYPE OF WASTE: *(Circle type)*

0 1 2 3 4 5 6

5. TYPE:

1) Incinerator, Single Chamber ☐ Multiple Chamber ☐

2) Waste Burner *(teepee, truncated cone, silo, other)* ______________

6. ARE INSTRUCTIONS FOR THE OPERATION OF THE INCINERATOR POSTED IN A CONSPICUOUS PLACE NEAR THE INCINERATOR? YES ☐ NO ☐

7. QUANTITY OF WASTE BURNED *(Circle appropriate units)*:

tons/year cubic yards/day pounds/hour ______________

8. OPERATION SCHEDULE:

________ Hours per day, ________ Days per week, ________ Weeks per year

________ Other ______________

9. TYPE OF WASTE BURNED	PERCENT BY VOLUME	PERCENT BY WEIGHT
Paper		
Cardboard		
Wood		
Plastic *(indicate chemical composition)*		
Rubber *(indicate chemical composition)*		
Garbage		
Pathological Waste		
Gaseous, Liquid, or Semi-liquid wastes *(indicate chemical composition)*		
Incombustibles		
Other *(specify)*		

10. PHOTOGRAPH OF UNIT -- ENCLOSE A MINIMUM SIZE PHOTOGRAPH OF 5" X 7".

11. PLAN OF THE UNIT -- MANUFACTURER'S DRAWING OR DRAWING CLEARLY ILLUSTRATING ALL DIMENSIONS AND CONSTRUCTION DETAILS MUST BE SUBMITTED.

DEP7007C
Continued

12. COMBUSTION AIR:

(a) DRAFT: Natural Draft ☐ Induced Draft ☐ Forced Draft ☐ Pressure ________ in. H_2O

(b) AIR DISTRIBUTION:

	OVERFIRE	UNDERFIRE	SECONDARY
Number of Ports			
Port Size (square inches)			
Air Flow (SCFM)			

13. STACK:

(a) Inside diameter ________ inches.

(b) Height above grates to top of stack ________ feet.

(c) Height of stack above any building or obstacle within 25 feet of the incinerator ________ feet.

(d) Spark Arrestor: Height ________ inches Screening openings ________ inches

(e) Stack Shell:

Type of material and thickness: ________

Type of refractory, thickness and temperature rating: ________

14. SHELL CONSTRUCTION:

(a) Type of material and thickness: ________

(b) Type of insulation and thickness: ________

(c) Type of refractory, thickness and temperature rating: ________

(d) Type of seams: ________

(e) Method used to tie refractory to outside shell: ________

15. AUXILIARY EQUIPMENT:

(a) DAMPER: Barometric ☐ Guillotine ☐ None ☐

(b) Primary burner *(combustion chamber)*:

Fuel: ________

BTU/hour rating: ________

(c) Secondary burner:

Fuel: ________

BTU/hour rating: ________

(d) Other *(specify)*: ________

16. CONTROL EQUIPMENT:

(a) Afterburner on stack exit ☐ Type: ________

(b) Scrubber ☐ Type: ________

(c) Other *(specify)*: ________

17. REGULATION COMPLIANCE:

(a) Have stack tests been performed on the unit? YES ☐ NO ☐

(b) Are the results of the stack tests enclosed and made a part of this permit application? YES ☐ NO ☐

(c) Are the results of the stack tests on file in the Division office? YES ☐ NO ☐

APC 110C (12/81)

DEP7007E

MONITORING EQUIPMENT

PERMIT APPLICATION

1. STACK GAS MONITORING EQUIPMENT:

Point of Emission Number	Pollutant Monitored	Monitoring Start-up Date	Equipment		Calibration Frequency	Distance to Nearest Flow Disturbance (feet)	
			Make	Model		Downstream	Upstream

2. ADDITIONAL STACK GAS MONITORING DATA:

Point of Emission Number	Additional Parameters Monitored	Normal Parameter Rate

APC 110E (12/81)

3. AMBIENT MONITORING EQUIPMENT:

Monitoring Station Number	Pollutant Monitored	Monitoring Start-up Date	Measurement Method	Equipment		Sampling Frequency or Interval	Calibration Frequency
				Make	Model		

4. Attach <u>Scale</u> <u>Drawings</u> of all stacks having monitoring equipment, showing locations of those stack gas monitoring devices. Also, include performance specifications for each stack gas monitoring device.

5. Attach a topo map showing locations of all points of emissions and the locations of all ambient monitoring equipment.

6. Attach a copy of the diffusion equation calculations used to determine the locations of the ambient monitoring equipment. Also, include performance specifications for each ambient monitoring device.

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Frankfort, Kentucky 40601

DEP7007F

EPISODE STANDBY PLAN

ID Number: ______________________

1. NAME OF FIRM OR INSTITUTION:
2. FACILITY LOCATION: *Street* *City* *County*
3. PERSON TO CONTACT REGARDING AN AIR POLLUTION EPISODE: Name: ______________________ Title: ______________________ Office telephone: ____________ Home telephone: ____________ ALTERNATE PERSON TO CONTACT: Name: ______________________ Title: ______________________ Office telephone: ____________ Home telephone: ____________

APC 110F (12/81)

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Frankfort, Kentucky 40601

DEP7007F

EPISODE STANDBY PLAN

GENERAL SOURCE INFORMATION

POINT OF EMISSION NUMBER AND SOURCE DESCRIPTION	NORMAL EMISSIONS (lbs/hr) PARTICULATES SO_2 HC CO NO_x	BASIS FOR ESTIMATE

APC 110F (12/81)

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Frankfort, Kentucky 40601

DEP7007F
CONTINUED

WARNING LEVEL STANDBY PLAN

POINT OF EMISSION NUMBER	POLLUTANT(S)	DESCRIPTION OF ACTION	RESULTING EMISSIONS (lbs/hr)	REDUCTION FROM ALERT (%)	TIME REQUIRED (hrs)

APC 110F (12/81)

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Frankfort, Kentucky 40601

DEP7007F
CONTINUED

ALERT LEVEL STANDBY PLAN

POINT OF EMISSION NUMBER	POLLUTANT(S)	DESCRIPTION OF ACTION	RESULTING EMISSIONS (lbs/hr)	REDUCTION FROM NORMAL (%)	TIME REQUIRED (hrs)

APC 110F (12/81)

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Frankfort, Kentucky 40601

DEP7007F
CONTINUED

EMERGENCY LEVEL STANDBY PLAN

POINT OF EMISSION NUMBER	POLLUTANT(S)	DESCRIPTION OF ACTION	RESULTING EMISSIONS (lbs/hr)	REDUCTION FROM WARNING (%)	TIME REQUIRED (hrs)

APC 110F (12/81)

Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL
Fort Boone Plaza
18 Reilly Road
Frankfort, Kentucky 40601

DEP7007G

COMPLIANCE SCHEDULES

Source: LOG. No.
Address: I.D. No.

Facility Type:

Point of Emission Number and Source Description	Control Plan Description	Pollutants	Regulation(s)	Step Code *	Step Date *

Milestones

1. Date of submittal of final control plan to appropriate agency.
2. Date of award of control device contract.
3. Date of initiation of on-site construction or installation of emission control equipment.
4. Date by which on-site construction or installation of emission control equipment is completed.
5. Date by which Final compliance is achieved.

* For each emission point listed, step codes 1 through 5 must be listed with associated dates by which the actions listed under "Milestones" will occur.
** Not acceptable without authorized signature and date.

(Signature & Title of person submitting compliance schedule) **

Date

APC 110G (1/80)

Kentucky Department for Natural Resources & Environmental Protection
Bureau of Environmental Protection
DIVISION OF AIR POLLUTION CONTROL

DEP7007N

AIR POLLUTION CONTROL EQUIPMENT

NAME OF COMPANY: ______________________

SECTION I. SUMMARY SHEET *(Make additional copies, if necessary)*

Emission Point Number	Facility Description	Control Equipment[1]			Stack Parameters[2]					Control Efficiency %	Capture[4] or Collection Efficiency %	Basis of Estimate
		Type	Date Installed	Cost $	Height ft.	Diameter[3] ft.	Temp. °F	Flow ACFM	Exit Velocity ft/sec.			

1 If a facility has secondary control equipment in addition to primary control equipment, use a separate line and indicate, under type, that it is a secondary control.

2 If there is no stack for a particular point, enter NA (Not Applicable).

3 If the stack is rectangular, specify the dimensions.

4 Capture or collection efficiency is the efficiency with which the pollutants are collected at the emission source before being sent to the control device.

APC 110N (12/81)

7007N Continued

EMISSION POINT NO.	NAME AND CHEMICAL COMPOSITION OF POLLUTANTS	GRAIN LOADING (Grains/SCF)		AMOUNT EMITTED			BASIS OF ESTIMATE
		INLET	OUTLET	MAXIMUM Lb/Hr.	MAXIMUM Tons/Yr.	AVERAGE Tons/Yr.	

Page ______ of ______

APC 110N (12/81)

DEP7007N
Continued

All efficiency estimates should be supported with a detailed explanation of the method of calculation and/or the source of information. Submit all pertinent drawings.
Describe briefly the disposal of particulates collected, scrubbing liquid and/or other wastes generated at the plant site:

SECTION II. SPECIFIC CONTROL EQUIPMENT

ADSORPTION UNIT

1. EMISSION POINT NUMBER OF ADSORPTION UNIT:

2. MANUFACTURER

3. MODEL NAME & NUMBER:

4. ADSORBENT:

   Activated Charcoal: Type ____________ Other *(specify)*: ____________

5. ADSORBATE(S):

6. NUMBER OF BEDS:

7. WEIGHT OF ADSORBENT PER BED:

   ____________ lb.

8. DIMENSIONS OF BED:

   Thickness in direction of gas flow ____________ inches; Cross-section area ____________ sq. inches

9. INLET GAS TEMPERATURE

   ____________ °F or ____________ °C

10. PRESSURE DROP ACROSS UNIT:

    ____________ inch water Gauge

11. TYPE OF REGENERATION:

    ☐ Replacement ☐ Steam ☐ Other *(specify)*: ____________

12. METHOD OF REGENERATION:

    ☐ Alternate use of beds ☐ Source shut down ☐ Other *(specify)*: ____________

13. TIME ON LINE BEFORE REGENERATION:

    ____________ minutes

14. EFFICIENCY OF ADSORBER:

    ____________ %

Page ______ of ______

APC 110N (12/81)

DEP7007N
Continued

AFTERBURNER
(Incinerator for Air Pollution Control)

1. **EMISSION POINT NUMBER OF AFTERBURNER:**

2. **MANUFACTURER:**

3. **MODEL NAME AND NUMBER:**

4. **COMBUSTION CHAMBER DIMENSIONS:**

Length ____________ inches; Cross-sectional area ____________ sq. inches

5. **INLET GAS TEMPERATURE:**

________ °F or ________ °C

6. **OPERATING TEMPERATURE OF CHAMBER:**

________ °F or ________ °C

7. **TYPE OF FUEL:**

____

Sulfur ____________ wt%

8. **BURNERS PER AFTERBURNER:**

____________ @ ____________ BTU/hr. each

9. **CATALYST USED:** ☐ NO ☐ YES

Describe Catalyst ____________________

10. **HEAT EXCHANGER USED:** ☐ NO ☐ YES

Describe Heat Exchanger ____________________

11. **GAS FLOW RATE:**

____________ scfm

12. **EFFICIENCY OF AFTERBURNER:**

____________ %

13. **COMPOSITION OF WASTE COMBUSTED:**

____

____

14. **QUANTITY OF WASTE COMBUSTED** *(specify units)*:

Per hour ____________ Per year ____________

15. **FUEL USAGE** *(specify units)*:

Type ____________ hourly ____________ per year ____________

16. **INCINERATOR RESIDENCE TIME:**

____________ sec.

17. **MOISTURE CONTENT OF EXHAUST GAS:**

____________ %

Page ______ of ______

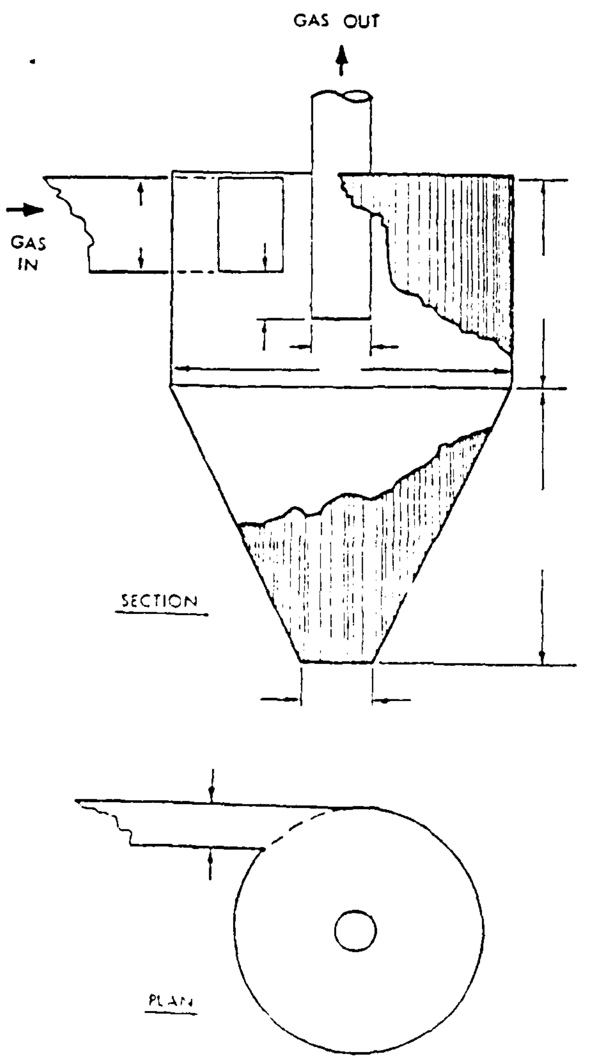
APC 110N (12/81)

7007N
Continued

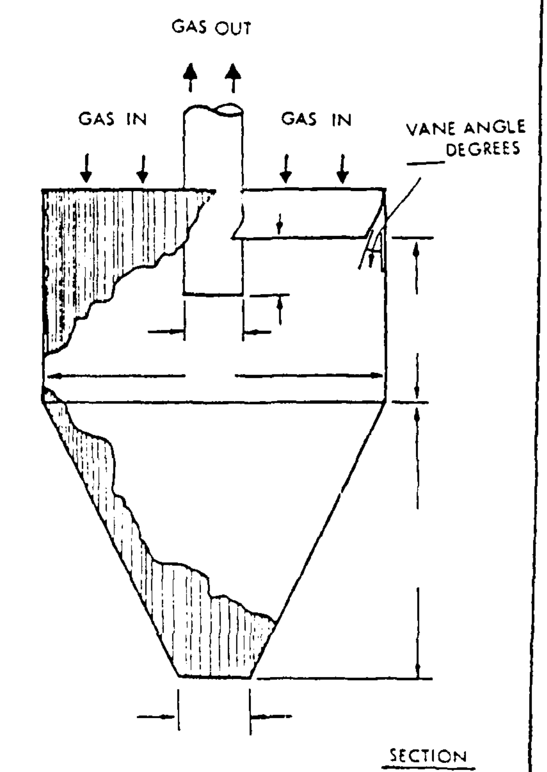
CYCLONE	
1. EMISSION POINT NUMBER OF CYCLONE:	
2. MANUFACTURER:	3. MODEL
4. TYPE OF CYCLONE: ☐ Single ☐ Multiple	5. NUMBER OF CYCLONES IN MULTIPLE CYCLONE:
6. GAS FLOW RATE: ____________ scfm	7. EFFICIENCY: ____________ %

8. DIMENSION THE APPROPRIATE SKETCH BELOW *(in inches)* OR PROVIDE A DRAWING WITH EQUIVALENT INFORMATION:

TANGENTIAL INLET CYCLONE



AXIAL INLET CYCLONE
(INDIVIDUAL CYCLONE OF MULTIPLE CYCLONE)



NOT TO SCALE

APC 110N (12/81)

CONDENSER

1. EMISSION POINT NUMBER OF THE CONDENSER:	
2. MANUFACTURER:	3. MODEL NAME AND NUMBER:
4. HEAT EXCHANGER AREA: ________ sq. ft.	5. COOLANT FLOW RATE: Water ________ GPM Air ________ scfm Other: Type ________ Flow Rate ________
6. GAS FLOW RATE: ________ scfm	7. COOLANT TEMPERATURE: In ________ °F; Out ________ °F
8. GAS TEMPERATURE: In ________ °F; Out ________ °F	9. EFFICIENCY OF CONDENSER: ________ %
10. COMPOSITION OF THE GAS AT THE: a. Inlet: b. Outlet:	

ELECTROSTATIC PRECIPITATOR

1. EMISSION POINT NUMBER OF PRECIPITATOR:	
2. MANUFACTURER:	3. MODEL NAME AND NUMBER:
4. COLLECTING ELECTRODE AREA: ________ sq. ft.	
5. GAS FLOW RATE: ________ scfm	6. EFFICIENCY: ________ %
7. VOLTAGE ACROSS THE PRECIPITATOR PLATES:	8. RESISTIVITY OF POLLUTANTS:
9. NUMBER OF STAGES IN THE PRECIPITATOR:	

Page ________ of ________

APC 110N (12/81)

DEP7007N
Continued

FILTER UNIT

1. EMISSION POINT NUMBER OF FILTER UNIT:

2. MANUFACTURER:

3. MODEL NAME AND NUMBER:

4. FILTERING MATERIAL:

5. FILTERING AREA:

6. CLEANING METHOD: ☐ Shaker ☐ Reverse Air ☐ Pulse Air ☐ Pulse Jet ☐ Other *(specify)*: ____________

7. GAS COOLING METHOD: ☐ Ductwork: Length ________ft; Diameter ________inches ☐ Heat Exchanger ☐ Bleed-in Air ☐ Water Spray ☐ Other *(specify)*: ____________

8. GAS FLOW RATE *(from source)*

________scfm

9. COOLING GAS FLOW RATE:

Bleed-in Air ________scfm;

water spray ________GPM

10. INLET GAS CONDITION:

Temperature ________°F; Dewpoint ________°F

11. EFFICIENCY OF FILTER UNIT:

SCRUBBER

1. EMISSION POINT NUMBER OF SCRUBBER:

2. MANUFACTURER:

3. MODEL NAME AND NUMBER:

4a. TYPE OF SCRUBBER:

☐ Venturi ☐ Wet Fan

☐ Packed; Packing type ________, Size ________, Packed height ________inches

☐ Spray; Number of Nozzles ________ Nozzle pressure ________psig

☐ Other *(specify)* ____________ *(Attach description and sketch with dimensions)*

b. PRESSURE DROP ACROSS THE SCRUBBER: ____________

5. TYPE OF FLOW: ☐ Cocurrent ☐ Countercurrent ☐ Crossflow

6. SCRUBBER GEOMETRY:

Length in direction of Gas Flow ________ft.; Cross-sectional area ________sq. ft.

7. CHEMICAL COMPOSITION OF SCRUBBING LIQUID:

8. SCRUBBING LIQUID FLOW RATE:

________GPM

9. GAS FLOW RATE:

________scfm

10. INLET GAS TEMPERATURE:

________%

11. EFFICIENCY OF SCRUBBER:

________%

APC 110N (12/81)

7007N
Continued

OTHER TYPE OF CONTROL EQUIPMENT	
1. EMISSION POINT NUMBER OF "OTHER TYPE" OF CONTROL EQUIPMENT:	
2. GENERIC NAME OF "OTHER" EQUIPMENT:	
3. MANUFACTURER:	4. MODEL NAME AND NUMBER:
5. DESCRIPTION AND SKETCH, WITH DIMENSIONS, FLOW RATES AND EFFICIENCY OF "OTHER" EQUIPMENT.	

Page ______ of ______

APC 110N (12/81)

Natural Resources & Environmental Protection Cabinet
Department for Environmental Protection
Division of Air Pollution Control

DEP 7007R

EMISSION REDUCTION CREDIT

1. NAME OF COMPANY: ______________________

2. EMISSION REDUCTION CREDIT (ERC) FOR POLLUTANT: *(Check one)*
   - ☐ TOTAL SUSPENDED PARTICULATE (TSP)
   - ☐ SULFUR DIOXIDE (SO_2)
   - ☐ VOLATILE ORGANIC COMPOUNDS (VOC)
   - ☐ CARBON MONOXIDE (CO)
   - ☐ NITROGEN OXIDES (NO_x)
   - ☐ LEAD (Pb)

3. EFFECTIVE DATE OF REDUCTION: ____ - ____ - ____

4. OPERATING SCHEDULE: ______ HR/DAY ______ DAY/WK ______ WK/YR

5. EMISSION POINT NUMBER: ______________________

6. PROCESS DESCRIPTION: ______________________

7. MAXIMUM OPERATING RATE: ______ *Before ERC Specify Units* ______ *After ERC Specify Units*

8. MAXIMUM ANNUAL THRUPUT: ______ *Before ERC Specify Units* ______ *After ERC Specify Units*

9. REASON FOR EMISSION REDUCTION (*Control Efficiency Increase, Production Rate Decrease, Shutdown, Etc.; Explain*):

10. EMISSIONS BEFORE REDUCTION: ______ TONS/YEAR

11. EMISSIONS AFTER REDUCTION: ______ TONS/YEAR

12. EMISSIONS TO BE BANKED: ______ TONS/YEAR

13. PROCESS PARAMETERS:

(a) STACK HEIGHT ______ FT

(b) STACK DIAMETER ______ FT

(c) EXIT GAS VELOCITY ______ FT/SEC

(d) EXIT GAS TEMPERATURE ______ °F

(e) PARTICLE SIZE ______ μm *(If Applicable)*

(f) LIST ANY HAZARDOUS MATERIAL(S) *(As specified in 40 CFR Part 260, Appendix VIII)* ______

14. EMISSION RATE *(After ERC)*: ______ LB/DAY ______ TON/YEAR

15. OTHER PERTINENT DATA *(If Applicable)*: ______________________

DEP7007S

SERVICE STATIONS:

A FOR ALL TANKS:

B FOR GASOLINE TANKS ONLY:

DOES THE TANK HAVE:

Tank ID Number	Product Stored	Tank Capacity (gallons)	Tank Dimensions Diameter (feet)	Tank Dimensions Length (feet)	Is it Underground (yes/no)	Does it have a Submerged Fill Pipe* (yes/no)	A Gauge Well Drop Tube Which Extends Within 6" of the Tank Bottom (yes/no)	A Vent Line Restriction* (yes/no)	A Vapor Balance System* (Yes/no)	An Interlocking System* (Yes/no)	What is the Fill Pipe Area (in^2)	What is the Vapor Return Line Area (in^2)

C ***What is the Annual throughput for:***

A. Regular Gasoline ____________ gallons

B. Unleaded Gasoline ____________ gallons

C. Premium Gasoline ____________ gallons

D. Diesel Fuel ____________ gallons

E. *Kerosene* ____________ gallons

F. Other ____________ gallons

D

____

Signature and Date

***DEFINITIONS**

(1) "Submerged fill pipe" means any fill pipe the discharge of which is entirely submerged when the liquid level is six (6) inches above the bottom of the tank; or when applied to a tank which is loaded from the side, shall mean any fill pipe the discharge opening of which is entirely submerged when the liquid level is two (2) times the fill pipe diameter above the bottom of the tank.

(3) "Vent line restriction" means:
(a) an orifice of one-half to three-quarters inch inside diameter; or
(b) A pressure-vacuum relief valve set to open at eight (8) oz. per square inch pressure and four (4) oz. per square inch vacuum; or
(c) a vent shut-off valve which is activated by connection of the vapor return hose.

(4) "Vapor balance sytem" means a system which conducts vapors displaced from storage tanks during filling operations to the storage compartment of the transport vehicle delivering the fuel.

(5) "Interlocking system" means devices which keep the storage tank sealed unless the vapor hose is connected or which prevent delivery of fuel until the vapor hose is connected.

E **NOTE: Prior to the installation of equipment to comply with air pollution control regulations, the source owner/operator is advised to obtain approval from the State Fire Marshall's office.**

APC-110-S

APPENDIX B:

STATE AIR QUALITY REGULATORY AGENCIES

Alabama

Stage Agency:

Alabama Air Pollution Control Commission
645 S. McDonough St.
Montgomery, AL 36130-1701
(205) 834-6570

City of Huntsville:

Air Pollution Control Department
City of Huntsville
2033 C Airport Road
Huntsville, AL 35802
(205) 881-7803

Jefferson County (includes City of Birmingham):

Jefferson County Department of Health
1400 Sixth Avenue, South
P.O. Box 2646
Birmingham, AL 35202
(205) 933-9110

Tricounty (Cullman, Lawrence, Limestone, and Morgan Counties):

The TriCounty District Health Service
Division of Air Pollution Control
510 Cherry Street, N.E.
P.O. Box 1628
Decatur, AL 35602
(205) 353-7021

Georgia

State Agency:

Environmental Protection Division
Department of Natural Resources
Air Protection Branch
270 Washington St., S.W.
Atlanta, GA 30334
(404) 656-4713

Kansas

State Agency:

Kansas Department of Health and Environment
Forbes Field
Topeka, KS 66620
(913) 862-9360

Kentucky

State Agency:

Division of Air Pollution Control
Department for Natural Resources
and Environmental Protection
Fort Boone Plaza
18 Reilly Road
Frankfort, KY 40601
(502) 564-3382

Massachusetts

Central Massachusetts:

Central Massachusetts Air Pollution Control District
75 Grove Street
Worchester, MA 01605
(617) 791-3672

Metropolitan Boston-Northeast Region:

Metropolitan Boston-Northeast Region
Air Section
323 New Boston Street
Woburn, MA 01810
(617) 727-2658; 935-2160

Southeastern Massachusetts:

Southeastern Massachusetts Air Pollution Control District
c/o Lakeville Hospital
Main Street
Lakeville, MA 02346
(617) 727-1440; 947-1231

Western Region:

Berkshire and Pioneer Valley Air Pollution Control Districts
1414 State Street
Springfield, MA 01101
(617) 727-8640

North Carolina

State Agency:

Division of Environmental Management
Air Quality Section
P.O. Box 27687
Raleigh, NC 27611
(919) 733-7015

Forsyth County:

Forsyth County Department of Public Health
301 N. Eugene Street
Greensboro, NC 27401
(919) 373-3771

Mecklenburg County:

Mecklenburg County Department of Environmental Health
Air Quality
1200 Blythe Blvd.
Charlotte, NC 28203
(704) 376-4649

Western North Carolina Region (Buncombe and Haywood Counties):

Western North Carolina Region Air Pollution Control
189 College Street
P.O. Box 7215
Asheville, NC 28807
(704) 255-5655

Oklahoma

State Agency:

Air Quality Service
Environmental Health Services
Oklahoma State Department of Health
1000 Northeast 10th Street
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-5520

Oklahoma County:

Air Quality Control Section
Oklahoma City-County Health Department
921 N.E. 23rd
Oklahoma City, OK 73105
(405) 427-8651

Tulsa County

Tulsa City-County Health Department
4616 E. 15th Street
Tulsa, OK 74112
(918) 744-1000

Pennsylvania

Allegheny County:

Mr. J. D. Graham, Engineer
Plan Review Section
Allegheny County Health Department
Bureau of Air Pollution Control
301 39th Street
Pittsburgh, PA 15201
(412) 681-6900

Philadelphia County:

Mr. John P. Daley
City of Philadelphia
Air Management Services
4320 Wissahickon Avenue
Philadelphia, PA 19129
(215) 686-1776

Region I (Berks, Bucks, Chester, Delaware, Lehigh, Montgomery, and Northhampton Counties):

Mr. James Donnelly
Engineering Services Chief
1875 New Hope Street
Norristown, PA 19401
(215) 631-2415

Region II (Carbon, Lackawanna, Luzerne, Monroe, Pike, Schuylkill, Susquehanna, Wayne, and Wyoming Counties):

Mr. Babu Patel
Engineering Services Chief
90 E. Union Street
Wilkes-Barre, PA 18703
(717) 826-2531

Region III (Adams, Bedford, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntington, Juniata, Lancaster, Lebanon, Mifflin, Perry, and York Counties):

Mr. Hartin Weiss
Engineering Services Chief
407 S. Cameron Street
Harrisburg, PA 17120
(717) 785-8162

Region IV (Bedford, Cameron, Centre, Clearfield, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, and Union Counties):

Mr. Richard Maxwell
Engineering Services Chief
200 Pine Street
Williamsport, PA 17701
(717) 327-3637

Region V (Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington, and Westermoreland Counties):

Mr. Ken Bowman
Engineering Services Chief
Room 851 Kossman Building
100 Forbes Avenue
Pittsburgh, PA 15222
(412) 565-2499

Region VI (Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango, and Warren Counties):

Mr. William Charlton
Engineering Services Chief
1012 Water Street
Meadville, PA 16335
(814) 724-8530

South Carolina

State Agency:

South Carolina Department of Health and Environmental Control
Bureau of Air Quality Control
2600 Bull Street
Columbia, SC 29201
(803) 758-5406

Utah

State Agency:

Utah Department of Health
Division of Environment
Bureau of Air Quality
150 West North Temple
Salt Lake City, UT 84110
(801) 533-6108

Virginia

Region I -- Southwest Virginia (Bland, Buchanan, Carroll, Dickenson, Grayson, Lee, Russell, Scott, Smyth, Tazewell, Washington, Wise, and Wythe Counties, and Cities of Bristol, Galax, and Norton):

Michael D. Overstreet
121 Russel Road
Abingdon, VA 24210
(703) 628-7841

Region II -- Valley of Virginia (Alleghany, Augusta, Bath, Botetourt, Clarke, Craig, Floyd, Frederick, Giles, Highland, Montgomery, Page, Pulaski, Roanoke, Rockbridge, Rockingham, Shenandoah, and Warren Counties, and Cities of Buena Vista, Clifton, Forge, Covington, Harrisonburg, Lexington, Radford, Roanoke, Salem, Staunton, Waynesboro, and Winchester, and Towns of Blacksburg, Christiansburg, Front Royal, Luray, Pulaski, and Vinton):

Donald L. Shepherd
Suite A, 5338 Peters Creek Road
Roanoke, VA 24019
(703) 982-7328

Region III -- Central Region (Amelia, Amherst, Appomattox, Bedford, Brunswick, Buckingham, Campbell, Charlotte, Cumberland, Franklin, Halifax, Henry, Lunenburg, Mecklenburg, Nottoway, Patrick, Pittsylvania, and Prince Edward Counties, and Cities of Bedford, Danville, Lynchburg, Martinsville, and South Boston, and Towns of Blackstone, Farmville, Rocky Mount, and South Hill):

William W. Parks
7701-03 Timberlake Road
Lynchburgh, VA 24502
(804) 528-6641

Region IV -- Northeastern Virginia (areas in this region are under the jurisdiction of the following Regions):

Region III -- Albemarle County, City of Charlottesville, Fluvanna County, Greene County, Louisa County, and Nelson County.

Region V: -- Essex County, Gloucester County, King and Queen County, King William County, Lancaster County, Mathews County, Middlesex County, Northumberland County, Richmond County, and Westmoreland County.

Region VI: -- Accomack County and Northampton County.

Region VII: -- Caroline County, Clarke County, Culpeper County, Fauquier County, Frederick County, City of Fredericksburg, King George County, Madison County, Orange County, Page County, Rappahannock County, Shenandoah County, Spotsylvania County, Stafford County, Warren County, and the City of Winchester.

Region V -- State Capital (Charles City, Chesterfield, Dinwiddie, Goochland, Greensville, Hanover, Henrico, New Kent, Powhatan, Prince George, Surry, and Sussex Counties and Cities of Colonial Heights, Emporia, Hopewell, Petersburg, and Richmond):

Henry A. Moss
8205 Hermitage Road
Richmond, VA 23228
(804) 264-3067

Region VI -- Hampton Roads (Isle of Wight, James City, Nanesmond, Southhampton, and York Counties, and Cities of Chesapeake, Franklin, Hampton, Newport News, Norfolk, Portsmouth, Suffolk, Virginia Beach, and Williamsburg):

Ramon P. Minx
Pembroke Office Park
Pembroke IV - Suite 409
Virginia Beach, VA 23462
(804) 499-6845

Region VII -- Northern Virginia (Arlington, Fairfax, Loudoun, Prince William Counties, and Cities of Alexandria, Fairfax, and Falls Church):

John C. Doherty
Springfield Towers - Suite 502
6320 Augusta Drive
Springfield, VA 22150
(703) 644-0311

Washington

Benton-Franklin-Walla Walla Counties:

Air Pollution Control Authority
650 George Washington Way
Richland, WA 99352
(509) 545-2354

Northwest (Island, San Juan, Skagit, and Whatcom Counties):

Northwest Air Pollution Authority
207 Pioneer Building
Mount Vernon, WA 98273
(206) 336-5705

Olympic Region (Clallam, Grays, Harbor, Jefferson, Mason, Pacific, and Thurston Counties):

Olympic Air Pollution Control Authority
120 E. State Avenue
Olympia, WA 98501
(206) 352-4881

Puget Sound (King, Kitsap, Pierce, and Snohomish Counties):

Puget Sound Air Pollution Control Agency
200 West Mercer Street
P.O. Box 9863
Seattle, WA 98109
(206) 344-7330

Southwest (Clark, Cowlitz, Lewis, Skanamia, and Wahkiakum Counties):

Southwest Air Pollution Control Authority
7601 N.E. Hazel Dell Avenue
Vancouver, WA 98665
(206) 696-2508

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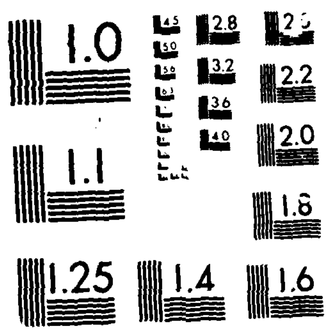

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